Major Commercial Nuclear Programs of the World

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Preface

Soon after the military nuclear weapons programs arising from World War II began to achieve their first successes, several countries began developing peaceful nuclear programs directed toward power generation and production of specialty nuclear materials. In the decades that followed, some countries developed their fledgling programs into major economic and technological successes. Other countries settled for more modest programs or looked to the future for greater promise. Each country's program has resulted from an evaluation of many factors: the role of nuclear energy in the future; the need for energy and economic security; the necessary investments, resources, and technologies, and; the environmental and proliferation risks of civilian nuclear programs. While developing their programs, all countries have learned to appreciate the dangers and challenges posed by the mere existence of some nuclear materials and the need to control and monitor the technologies and materials borne from these nuclear programs.

This summary presents brief descriptions and statistics of seven of the major national commercial nuclear programs in the world (excluding the United States), including the other four declared nuclear weapons states (Russia, the People's Republic of China, the United Kingdom, and France), Germany, Japan, and South Korea. Data for this summary has been collected from publicly available sources.

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1.0 France

1.1 Nuclear Program

1.1.1 History to Date

The commercial nuclear power infrastructure in France is often viewed as the most comprehensive in the world and is larger than that of any other country except the United States. The infrastructure includes several key facilities, particularly some of its power reactors and reprocessing facilities, that historically have been shared by France’s commercial and military nuclear programs. Many of its key facilities also provide nuclear fuel cycle services to several foreign nations. France uses nuclear reactors to satisfy about three-quarters of its internal electric power demand and has developed facilities to perform most services needed to support a closed nuclear fuel cycle, including conversion, enrichment, fuel fabrication, reprocessing, mixed-oxide (MOX) fuel fabrication, and low-level waste disposal.

Reactors. The French nuclear program began with the development of a natural-uranium gas-graphite (NUGG) reactor technology for the French military. The French commercial nuclear reactor program began in the 1950s with the use of the NUGG reactor technology. The first commercial French NUGG reactor began operation in 1964 at Chinon, and five additional NUGG reactors began operation by 1972. A major driver of the commercial nuclear program was France's desire to reduce its dependence on imported fossil fuels and to improve its energy security.

In 1969, France decided to transition its commercial reactor technology to the pressurized-water reactor (PWR) design. Between 1977 and 1997, 57 PWRs entered commercial service. By the end of 1993, French power reactors had discharged nearly 21,000 metric tons (MT) of spent fuel. By May 1994, all French NUGG reactors had been shut down with the closing of the Bugey 1 reactor. France was the first country to expand the use of MOX fuel in light water reactors. Beginning in 1987, Electricité de France, the major government-owned power utility, began to load its PWRs with MOX fuel. By the end of 1995, France had loaded 245 MT of MOX fuel into its PWRs, most of it using a 1/3-core MOX, 2/3-core uranium configuration.[1]

France also experimented with fast breeder reactor (FBR) technology. France's FBR experience includes three FBRs: the experimental Rapsodie FBR, which began operation in 1967; an industrial scale prototype FBR, Phenix, which began operation in 1974, and; the 1,240-MWe Superphenix, which began operation in 1985. France recently decided to close the Superphenix FBR.

[1] *Plutonium and Highly Enriched Uranium 1996 World Inventories, Capabilities, and Policies*; D. Albright, F. Berkhout, and W. Walker; Stockholm International Peace Research Institute; Oxford University Press; 1997. pp. 166, 217.

Conversion. Conversion of uranium concentrate (U_3O_8) to UF_4 and uranium metal in France was first performed by the Commissariat à l'Énérgie Atomique (CEA) at the Le Bouchet Centre near Paris. Since 1959, these processes were performed at the Malvesi plant. In 1962, the Société de Usines Chimiques de Pierrelatte (SUCP) began operation of a UF_4 to UF_6 conversion plant at Pierrelatte. In 1971, the Société pour la Conversion de l'Uranium en Metal et en Hexafluorure (COMURHEX) was incorporated to produce UF_6 for French PWRs.

Enrichment. The French military program began development of gaseous diffusion technology for uranium enrichment in 1953. In 1957, the CEA built a pilot gaseous diffusion facility at Saclay. By 1967, a military uranium enrichment facility, Usine de Pierrelatte, was completed. The Pierrelatte plant began producing enriched uranium for the civilian power program in the early 1970s. In 1969, France announced its intention of promoting a common European enrichment facility and by 1973, France, Belgium, Italy, and Spain established Eurodif SA. Iran later joined Eurodif SA. The Eurodif effort resulted in construction of a 10,800-MTSWU (metric tons separative work unit) gaseous diffusion enrichment plant at Tricastin. Construction of this plant started in 1974, startup occurred in 1978, and the plant reached nominal capacity in 1982. With the successful operation of the Tricastin, Pierrelatte operations decreased, eventually ending in 1995.[2]

Uranium Fuel Fabrication. Fuel for France's NUGG reactors was originally designed by the CEA and fabricated by industrial companies in France. Commercial production of PWR fuel for French PWRs began with the 1973 establishment of Franco-Belge de Fabrication des combustibles (FBFC). FBFC was initially licensed to use Westinghouse fabrication technology, and FBFC took over an existing fabrication facility in Dessel, Belgium, which today has a 400 MTU (metric tonnes uranium) capacity for fuel pellet and assembly production. FBFC constructed a fuel fabrication plant, which began operating in 1979, in Romans, France. Another uranium fuel fabrication plant is located at Pierrelatte.

Reprocessing. France has operated several major reprocessing facilities for LWR, FBR, and NUGG reactor fuel in its history, three of which still operate. French spent fuel reprocessing technology was developed by the CEA, and France's first reprocessing plant was the Usine de Plutonium 1 (UP1) plant in Marcoule. In 1958, UP1 began separating plutonium from the spent fuel of three military production reactors located at Marcoule. In addition reprocessing military reactor fuel, UP1 reprocessed an estimated 5,300 MT of spent fuel from NUGG power reactors by 1993, recovering about 10.3 MT of plutonium. UP1 was shut down in 1997.[3]

To increase reprocessing capacity for commercial NUGG fuel, France constructed and began operating a second plant, UP2, at La Hague in 1966. UP2 was also used for both military and civilian reprocessing. France added an oxide head-end to UP2 in 1974 subsequent to a decision to switch from NUGG reactors to PWRs, and UP2 was reprocessing about 400 MT of oxide fuel per year by the late 1980s. By 1987, UP2 had reprocessed 4,900 MT of NUGG fuel,

[2] Ibid. pp. 122-123

[3] Ibid. pp. 165, 166, 482.

and by the time it completed the shift from metal NUGG fuel to oxide PWR fuel, over 11,000 MT of NUGG fuel containing about 20 MT of plutonium had been reprocessed in France. A state-owned company, Compagnie Générale des Matières Nucléaires (COGEMA), took over UP2 from the CEA in 1976, and several modifications and additions to UP2 have resulted in the plant currently having an annual capacity of 850 MT for oxide fuels. Since 1992, UP2 has been dedicated to reprocessing spent fuel discharged by French PWRs. By the end of 1993, UP2 had recovered about 40 MT of plutonium, including about 30 MT from LWRs.[4]

COGEMA began construction of France's most recent reprocessing facility, UP3, in 1978, and this facility began operating in 1989. Its annual capacity is about 800 MT of oxide fuel. Foreign (i.e., non-French) reprocessing customers financed construction of UP3, and the first ten years of UP3 operations were dedicated to reprocessing spent fuel from non-French reactors, primarily that of Germany and Japan. By the end of 1993, it had recovered about 11 MT of plutonium.[5]

In addition to these three major reprocessing plants, France operated several pilot-scale plants used to reprocess FBR spent fuel.

MOX Fuel Fabrication. There have been three MOX fuel fabrication plants in France. The first plant, Cadarache ATPu, was operated by the CEA from 1970 to 1989 with a capacity of 15 MT per year for FBR fuel. The second plant, Complex de Fabrication de Cadarache (CFCa), was originally a CEA facility that began operation in 1989 as a MOX fabrication plant for FBRs. The CFCa is now owned by COGEMA and has a capacity of 35 MTHM for pellet and rod production. The third plant, the 160 MT MELOX plant, is also owned by COGEMA and began operation in 1995.[6]

France and COGEMA have a major influence on a fourth MOX fabrication plant, the Belgonucleaire P0 plant in Dessel, Belgium, and ships MOX rods from CFCa to Dessel for final assembly. About 25 MT of P0's 35 MT annual capacity is used to supply MOX fuel to France.[7]

Waste Management. ANDRA, France's national agency for radioactive waste management, was created in 1979. It has operated two industrial sites, located at Manche near La Hague and at Aube in northeastern France, for the receipt, conditioning, and disposal of short-lived low-level waste (LLW) and intermediate-level waste (ILW). The Manche site opened in 1969 and closed in 1994. The second site, Aube, opened in 1992. Development programs for high-level waste (HLW) disposal are under way as a result of government directives.

[4] Ibid. pp. 165-167, 482-483.

[5] Ibid. p. 483.

[6] Ibid. p. 197

[7] Ibid. p. 215.

1.1.2 Current Status

Because of its strategic importance, the French nuclear energy system is characterized by strong state involvement. The nuclear industry is dominated by state-owned monopolies. COGEMA provides fuel cycle products and services directly or through its subsidiaries, CEA directs nuclear research and development (R&D), and Electricité de France (EDF) owns and operates reactors. Framatone, the reactor vendor for EDF, is not state owned. Framotone and COGEMA jointly own (on a 50 percent each basis) Fragema, which serves as EDF's fuel vendor. EDF is the world's largest utility and is respected worldwide for its commitment to and influence on the nuclear industry. COGEMA has industrial capabilities in all activities associated with the nuclear fuel cycle from uranium mining to spent fuel reprocessing and recycling. ANDRA is responsible for designing, constructing, and managing long-term waste disposal facilities. ANDRA also supports the research and development of long-term waste disposal, and establishes the regulation for the packaging and disposal of such waste.[8]

1.1.3 Current Strategy

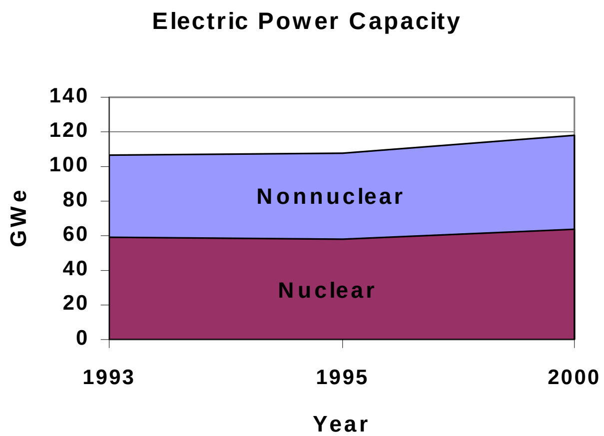
The French nuclear commercial program currently depends primarily on PWRs and the reprocessing and recycling of spent nuclear fuel. However, a long period of expansion for this program appears to be ending. As the supplier of commercial electric power that is primarily dependent on nuclear technology, EDF is under increasing economic pressure resulting from liberalization of electricity markets which has essentially prohibited further investment in new reactors at this time. As a result of reducing market demand and the need to reduce costs, EDF is scheduling a reduction in its uranium handling operations. There are no substantive plans for new reactors, and the French government has approved the closure of the Superphenix FBR.

[8] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/france/factsheet.html.

1.2 Statistics

1.2.1 Nuclear Profile

Total nuclear power production (1996)[9]	370 TWh
Percent of total power production that is nuclear (1996)[10]	77%
Total nuclear power exports	70 TWh
Total nuclear generating capacity (1997)[11]	58 GWe
Number of operating commercial reactors (1997)[12] TOTAL PWR FBR	 58 57 1
Percent of world nuclear generating capacity	24%



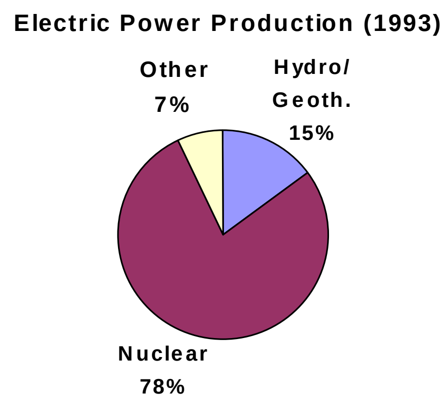


Chart data from: Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/france/factsheet.html.

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[9] 1996 data from IAEA.

[10] Ibid.

[11] *World Nuclear Performance*. Feb. 1998. Vol 13, Issue 2.

[12] *World Nuclear Industry Handbook 1998*. Nuclear Engineering International.

1.2.2 Fuel Cycle Facilities

Exhibit 1-1. Commercial Nuclear Fuel Cycle Facilities Located in France

Fuel Cycle Step	National Requirement (annual)	Company/Facility*	Operating Period	Capacity Data (Annual)
Uranium Production	10,000 MT U_3O_8	*COGEMA/Herault*	*1981 - present*	*1000 MT*
		COGEMA/La Crouzille	*- 1996*	*1000 MT*
		TCM/Bertholene	*1982 - present*	*70 MT*
		TCM/Le Bernerdan	*1979 - present*	*550 MT*
		MOKTA/Le Cellier	*1977 - present*	*300 MT*
		Doug Triea/Mailhac	*1979 - present*	*500 MT*
		SIMURA/Inguiniel	*Shut Down*	
Conversion (U_3O_8 to UF_6)	8,900 MTU (1998)	*COMHUREX/Malvesi*	*- present*	*14,000 MTU*
Conversion (UF_4 to UF_6)		*COMHUREX/Pierrelatte (NatU)*	*1971 - present*	*14,000 MTU*
Conversion (RepU to UF_6)		*COMHUREX/Pierrelatte (RepU)*	*- present*	*350 MTU*
Enrichment	6,100 MTSWU (1998)	Eurodif/Tricastin	1978 - present	10,800 MTSWU
		Pierrelatte	1967 - 1995	500 MTSWU (estimate)
Uranium Fuel Fabrication	N/A	FBFC/Romans	1979 - Present	750 MTU PWR pellet and assembly production; and 1,300 MTU powder production
		FBFC/Pierrelatte	*- present*	*500 MTU PWR, LWR MOX*
		FBFC/Dessel	- present	450 MTU[13]
Reprocessing	N/A	CEA/Marcoule UP1	1958 - 1997	
		COGEMA/La Hague UP2	1966 - present	850 MTHM
		COGEMA/La Hague UP3	1989 - present	*800 MTHM* Dedicated to non-French fuel through 1999
MOX Fuel Fabrication	N/A	COGEMA/Cadarache	1963 - present	35 MTHM
		COGEMA/MELOX	1995 - present	120 MTHM (being upgraded to 210 MTHM)
LLW Disposal	N/A	ANDRA/Manche	1969 - 1994	
		ANDRA/Aube	1992 - present	
HLW Storage	N/A	*COGEMA/La Hague*	*- present*	*14,500 MTHM Storage*

* See Appendix B for a list of acronyms.
** Italicized data from World Nuclear Industry Handbook 1998. Nuclear Engineering International. p. 120-127.

[13] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/france/factsheet.html.

Exhibit 1-2. Non-Domestic Fuel Cycle Facilities Supplying France

Fuel Cycle Step	Location	Company	Supplied to France
Uranium Production	Australia, Canada, Gabon, Niger, and United States	COGEMA	Majority of national requirement
	Namibia	Rossing	About 5% of national requirement
	Australia	Western Mining Company	Combined about 5% of national requirement
	Australia	ERA	
Conversion (U_3O_8 to UF_6)	United Kingdom	BNFL	Combined about 10% of national requirement
	United States	ConverDyn	
Enrichment	No information	Urenco	10% of national requirement
	Russia	Tenex	5% of national requirement
	United States	United States Enrichment Corporation	No information
Uranium Fuel Fabrication	Dessel, Belgium	FBFC	400 MTU capacity for fuel pellet and assembly production
MOX Fuel Fabrication	Dessel, Belgium	Belgonucleaire (P0)	35 MTHM (Capacity)

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2.0 Japan

2.1 Nuclear Program

2.1.1 History to Date

Japan's nuclear program originated in the 1950s as part of the international cooperation on nuclear technology initiated by President Eisenhower's Atoms for Peace Program. At that time, Japan's energy policy was directed towards improving the energy supply structure while reducing reliance on foreign energy sources. In 1955, Japan's Atomic Energy Comission (AEC) was formed to develop a national policy on the use and regulation of nuclear technology. In 1956, Japan established the Science and Technology Agency (STA) to develop and administer nuclear research and development (R&D) programs including research reactors. In 1957, the Japan Atomic Power Company (JAPC) was formed to build and operate the first commercial nuclear reactor. The Japan Demonstration Power Reactor (JDPR), a 13 megawatts electric (MWe) boiling water reactor (BWR) went online in 1963 followed by the first commercial power reactor, Tokai 1, a Magnox-fueled 166-MWe gas-cooled reactor (GCR) in 1966. A number of Japanese utilities placed orders with U.S. vendors (General Electric and Westinghouse) to provide the first commercial LWRs and, as a result, 22 light water reactors went into operation within the next 10 years.

Japan believed that future reliance on U.S. reactor technology was not in its best interests, and it established the Power Reactor and Nuclear Fuel Development Corporation (PNC) to develop domestic technology in advanced thermal reactors (ATRs) and FBRs. In the late 1970s, PNC developed the Fugen (166-MWe ATR) and Joyo (100 MWt FBR) reactors and began operation of the Tokai-mura reprocessing plant. Unlike other reprocessing plants that separately produce uranium and plutonium, the Tokai-mura plant produces a single uranium-plutonium nitrate stream. Excluding a plutonium separation capability from Tokai-mura was a nonproliferation concession to the United States. The Tokai plant has a capacity of 210 MT, but it had only reprocessed 700 MT by the end of 1993, including a combination of PWR, BWR, and ATR fuels. It has not operated at full capacity for at least two reasons: technical problems and the insistence of its utility customers that it reprocess their fuel in separate campaigns.[14]

To support operation of the Tokai Magnox reactor, Japan has sent fuel to the UK Sellafield reprocessing facilities since it first began discharging spent fuel in 1967. By the end of 1993, 1,100 MT of Magnox fuel from Japan had been reprocessed at the Sellafield B205 facility, producing 2.1 MT of plutonium. Since the 1970s, a portion of Japan's separated plutonium was returned from the UK in several shipments. Japan has also sent LWR oxide spent fuel to

[14] *Plutonium and Highly Enriched Uranium 1996 World Inventories, Capabilities, and Policies*; D. Albright, F. Berkhout, and W. Walker; Stockholm International Peace Research Institute; Oxford University Press; 1997. pp. 156, 177.

France's UP2 and UP3 facilities for reprocessing, producing over 6 MT of separated plutonium by the end of 1993.[15]

In 1978, Japan formed the Nuclear Safety Commission (NSC), separating safety and health responsibilities from the AEC. The NSC was also responsible for implementing policies regulating nuclear installations. With the formation of the NSC, Japan's nuclear sector was divided into three areas:

Area	Agency
1. Nuclear power technology development	AEC
2. Nuclear safety and regulation	NSC
3. Research programs	STA

In the 1980s, the Japanese nuclear program added 15 LWRs, increasing its nuclear capacity by 12,300 MWe. By the end of 1989, the installed nuclear capacity was 27,500 MWe. Also during the 1980s, PNC started the construction of a FBR prototype reactor, the 280 MWe Monju at Tsuruga. The Monju reactor began operation in 1994and shut down in late 1995 after a sodium leak. In 1991, Japan ordered its first advanced boiling water reactors (ABWR), and two ABWRs subsequently began operation in 1996 and 1997.[16]

In the last 3 years, Japan's nuclear program experienced two accidents that have had a significant negative effect on the program. In 1995, the Monju prototype FBR experienced as sodium leak and was shut down. In 1997, an explosion and fire occurred at the Tokai-mura reprocessing plant's bitumenization facility. Following that incident, the Tokai plant also shut down after 20 years of operation.

2.1.2 Current Status

Japan has an official target of about 70 gigawatts electric (GWe) of nuclear capacity by 2010. However, in reality no more than 52 GWe of nuclear capacity is expected to be in place by 2010. Japan is currently constructing one nuclear power plant, Tohoku's Onagawa-3 (825 MWe BWR), and this facility is expected to begin commercial operation in 2002. Four other reactors are in the formal planning stage, representing about 5,200 MWe in future capacity:

- Higashidori-1 (1,100-MWe BWR)
- Hamaoka-5 (1,356-MWe ABWR)
- Shika-2 (1,356-MWe ABWR)
- Ohma (1,380-MWe ABWR)

[15] Ibid. pp. 276, 189.

[16] Ibid., pp. 202-203

The short-term future outlook of commercial reactors, as planned, consists of three ABWRs and two BWRs to be in operation by 2005 providing an additional capacity of 6,022 MWe to the Japanese grid.

The fuel cycle strategy is oriented towards reducing uranium demand and high-level nuclear waste by recycling plutonium in MOX fuel. These projects could be affected by the recent economic crisis in Japan. In effect, the budgets for the nuclear activities of the Ministry of International Trade and Industry (MITI) and STA have already been cut. However, it is unclear what the effect would be if Japan were to decide to shift its energy policy. In spite of these uncertainties, the Japanese economic crisis has helped keep nuclear power out of the media attention, which is, in essence, positive for nuclear energy proponents from a political standpoint.

Nuclear fuel cycle facilities under construction or in operation in Japan include facilities for enrichment, uranium fuel fabrication, and reprocessing. Japan Nuclear Fuels, Ltd. (JNFL) is operating and building in phases a 1,500 MTSWU enrichment facility at Oishitai, Rokkashomura. This facility is expected to be complete and reach full-scale operation by 2000. There are also five operating uranium fuel fabrication facilities and two reprocessing plants in Japan, but neither of the reprocessing plants is currently operating. The Tokai-mura reprocessing plant closed in 1997 following an accident and is not expected to re-open. The second reprocessing plant, an 800 MTHM plant financed by utilities, is being constructed by JNFL at Rokkasho-mura and is scheduled to begin operating in 2010.

Amid the political debate that now exists, the government's focus has shifted towards fostering more open communication and reforming the nation's long-term nuclear program. In addition, the private sector has reaffirmed its commitment to nuclear power and has been more predisposed to public information disclosure. The interaction among the government, local prefectures and the utilities has helped to erode the negative image created by the Monju and Tokai accidents, but the level of public support is not as high as before those events occurred.

The Japanese nuclear program continues to enjoy the support of the central government, but has lost support from the local prefectures. The setbacks at Monju and Tokyo Reprocessing Plant (TRP) provided anti-nuclear activists with the opportunity to protest the national nuclear energy policy, particularly the back-end strategy. Some of the anti-nuclear support eroded in 1997, after the government and nuclear utilities reaffirmed their commitments to nuclear power and spent fuel reprocessing. Despite this, the current thinking about achieving the closed cycle strategy prevails, but this could be affected by future political intervention.

In addition to political factors, another major external influence on the nuclear program is proposed government reform. A plan was proposed to reduce the number of central government ministries and agencies from 21 down to 12 by 2001. The proposal calls for the unification of STA and the education ministry to form the Ministry of Education, Science and Technology (MEST). This ministry would be in charge of academic research, science, and technology. Plans also call for MITI to become the Ministry of Economic and Industry (MEI), which will focus on issues related to the development and use of energy in general.

Except for JAPC, which is partially owned by the utilities, the Japanese utilities are privately owned and vertically integrated companies. These utilities have a financial interest in JAPC, which owns and operates three nuclear reactors and is involved in FBR development, as well as in the Electric Power Development Corporation (EPDC), which is in charge of developing electric generation projects. The private utilities and other private companies also have investments in the Central Research Institute of Electric Power Industry (CRIEPI) and Japan Nuclear Fuels Ltd. (JNFL).

The current government organizations responsible for supervising the Japanese nuclear programs are as follows:

- AEC-Serves as lead advisor to Japan's Prime Minister and provides the national policies on nuclear energy R&D and utilization.

- NSC-Serves as lead advisor on safety matters to the Prime Minister; carries out the national nuclear energy safety and security policies, as well as related R&D and utilization policy.

- STA-Provides technical support to the AEC and NSC and formulates the guidelines for science and technology development in all areas of the nuclear program including research and development.[17]

- MITI-Provides the supervision of industrial and energy activities, including commercial nuclear power. It also coordinates the licensing process for nuclear installations and serves as the national entity for industrial development.

- PNC-Performs nuclear fuel cycle research and development and advanced reactor R&D. It owns and operates a number of research facilities, the ATR and FBR reactors.

- Japan Atomic Energy Research Institute (JAERI) - Nuclear applied research and research reactor development.

In addition, the following five smaller organizations perform nuclear program-related duties in Japan:

- Atomic Energy Bureau (AEB)
- National Safety Bureau (NSB)
- Radiation Council (RC)
- Institute of Physical and Chemical Research (IPCR)
- National Institute of Radiological Sciences (NIRS)

[17] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/japan/factsheet.html.

Japan has established a number of waste management-related research programs around the country. JAERI, PNC, and the Radioactive Waste Management Center have been performing waste management R&D. In addition, PNC is planning to build a radioactive waste research center in Honorobe at Hokkaido. However, these responsibilities may change as the result of the political debates following the accidents at Monju and Tokai.

2.1.3 Current Strategy

After the December 1997 Kyoto summit, Japan's official strategy was to commit to further development of its nuclear power generation capacity in order to meet its CO_2 emission targets. The government continues to support nuclear power and closure of the fuel cycle, including reprocessing. These two aspects represent the current Japanese nuclear energy policy, summarized below:

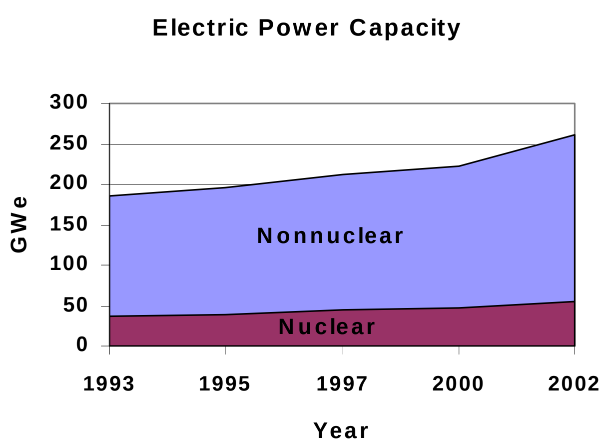
Topic	National Policy
National Energy Policy	Diversify the energy mix, reduce oil consumption and promote energy conservation
Nuclear Power Policy	Promote the development of the FBR program as a long-term energy strategy; install LWRs to meet short-term energy needs
Nuclear Fuel Cycle Policy	Acquire and secure uranium resources worldwide, promote the development of the closed fuel cycle, and develop enrichment, reprocessing, and waste management capacity (procure foreign reprocessing services until domestic capacity is available)
Waste Management	Develop a permanent deep underground repository for vitrified HLW, operate a LLW shallow land burial facility at Rokkasho-mura

2.2 Statistics

2.2.1 Nuclear Profile*

Total nuclear power production (1996)[18]	290 TWh
Percent of total power production that is nuclear (1996)[19]	33%
Total nuclear generating capacity (1997)[20]	43 GWe
Number of operating commercial reactors[21] TOTAL PWR BWR Magnox FBR Other	 53 23 28 1 1 1
Percent of world nuclear generating capacity	19%

* 1997 data except where noted.



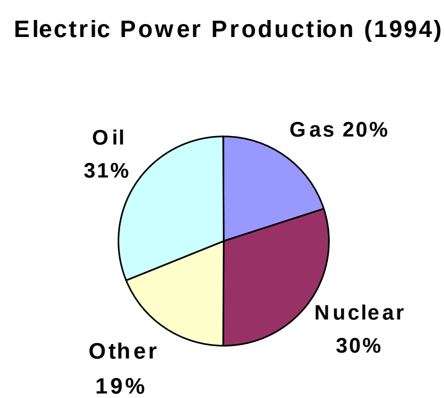


Chart data from: Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/japan/factsheet.html.

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[18] 1996 data from IAEA.

[19] Ibid.

[20] *World Nuclear Performance*. Feb. 1998. Vol 13, Issue 2.

[21] *World Nuclear Industry Handbook 1998*. Nuclear Engineering International.

2.2.2 Fuel Cycle Facilities

Exhibit 2-1. Commercial Nuclear Fuel Cycle Facilities Located in Japan

Fuel Cycle Step	National Requirement (Annual)	Company/Facility	Operating Period	Capacity Data (Annual)
Uranium Production	9,100 MT U_3O_8	*PNC/Toge*	*- 1981*	*50 MT*
		MMA/NIURES	*1986 - 1989*	*10 kg*
Conversion (U_3O_8 to UF_6)	9,000 MTU (1998)	JCO/Tokia-mura,		
		Ningyo R&D/Tomatagun,		
		PCDF/Tokia-mura,		
		PNC/Toge	*1982 - present*	*120 MTU*
Enrichment	5,500 MTSWU (1998)	PNC/Ningyo-Toge (gas centrifuge)	*1989 - present*	200MTSWU
		JNFL/Rokkasho-mura (gas centrifuge)	*1992 - present*	825 MTSWU (1998), 1,500 MTSWU (2000)
Uranium Fuel Fabrication	N/A	PNC/Tokai	- present	40 MTHM (ATR); 5 MTHM (FBR)
		JNFL/Yokosuka	*1970 - present*	750 MTHM (BWR)
		Mitsubishi Nuclear Fuel Co./Tokia-mura	*1980 - present*	440 MTHM (PWR)
		Nuclear Fuel Industries/Tokia-mura	- present	200 MTHM (BWR)
		Nuclear Fuel Industries/Kumatori 1&2	1970 - present	320 MTHM (PWR)
		Sumitomo/Tokia-mura	- present	750 MTHM UO_2 powder production
Reprocessing	N/A	JNFL/Rokkasho-mura	Startup scheduled 2010	800 MTHM
		PNC/Tokai-mura	1977-1997	90 MTHM
LLW Disposal	N/A	JNFL/Rokkasho-mura	1992 - present	200,000 m^3
HLW Storage	N/A	JNFL/Tokia-mura	1977 - present	
		JNFL/Rokkasho-mura	1995 - present	1,440 canisters

* Italicized data from World Nuclear Industry Handbook 1998. Nuclear Engineering International. p. 120-127.

Exhibit 2-2. Non-Domestic Fuel Cycle Facilities Supplying Japan

Fuel Cycle Step	Location	Company	Supplied to Japan
Uranium Production	Canada	CAMECO	20% of national requirement
	Australia	Energy Resources of Australia (ERA)	20% of national requirement
	Various	COGEMA (France)	10% of national requirement
	Australia, Canada, China, Namibia, Niger, South Africa, and United States	Various Suppliers	
Conversion (U_3O_8 to UF_6)	France	COMURHEX	35% of national requirement
	United Kingdom	BNFL	30% of national requirement
	Canada	Cameco	30% of national requirement
Enrichment	United States	United States Enrichment Corporation	60% of national requirement
	No information	Eurodif	20% of national requirement
Uranium Fuel Fabrication	United States	General Electric	UO_2 powder
Reprocessing	France	COGEMA	All of national requirement
	United Kingdom	BNFL	
MOX Fuel Fabrication	France	COGEMA	
	United Kingdom	BNFL	

3.0 The United Kingdom

3.1 Nuclear Program

3.1.1 History to Date

Reactors. Unlike the nuclear programs in most other western countries that are based on enriched uranium oxide-fueled light water reactors, the nuclear program in the United Kingdom (UK) historically has been based on a natural uranium metal-fueled gas-cooled graphite-moderated reactor design known as Magnox. The Magnox reactor was a UK design originally intended for the production of weapons-grade plutonium. In 1956, the first commercial nuclear power reactor in the UK began operation at Calder Hall. This Magnox reactor was operated by a state-owned corporation, British Nuclear Fuels plc. (BNFL). The BNFL Magnox reactors at Calder Hall were followed by a series of larger commercial units operated by two other government-owned organizations, the Central Electricity Generating Board (CEGB) and South of Scotland Electricity Board (SSEB). The CEGB and SSEB Magnox reactors were fueled with uranium from Canada, Australia, and Africa, and a government-owned stockpile established to ensure a secure supply of uranium.

Like the early NUGG reactors in France, the Magnox reactors operated by BNFL, CEGB, and SSEB had dual civilian-military functions. They produced electricity for civilian purposes and a portion of their spent fuel and other targets was reprocessed to produce plutonium and tritium for the UK weapons program. These reactors also produced plutonium that was traded to the U.S. for tritium and highly enriched uranium. These reactors were last used for military purposes in the late 1980s.[22]

After the Magnox reactors were built, a second generation of commercial reactors were constructed using an advanced gas reactor (AGR) design. The AGR design used enriched uranium as fuel and also allowed, in theory, for on-load refueling. Average fuel burn-ups in the AGRs were up to five times higher than that in Magnox reactors. In general, the AGRs did not perform as well as the Magnox reactors. There were large schedule and budget overruns on AGR construction, and AGR performance was also below expectations for many years after initial startup. As a result, the British commercial nuclear program, which had been ahead of other European countries, began to lose its lead.

In 1979, the incoming conservative government under Prime Minister Margaret Thatcher supported an ambitious 15-GWe expansion program based on PWR technology. A design for a 1,188-MWe PWR was drawn up in partnership with Westinghouse and, after a three-year public inquiry, approval was finally granted in 1987 for the construction of the first of the new PWRs at the Sizewell 'B' site. By then, the PWR program had been scaled down to only four

[22] *Plutonium and Highly Enriched Uranium 1996 World Inventories, Capabilities, and Policies*; D. Albright, F. Berkhout, and W. Walker; Stockholm International Peace Research Institute; Oxford University Press; 1997.

reactors in addition to Sizewell and, by 1989, even this reduced program was canceled as the UK electric power supply industry began to be privatized.

Prior to 1990 the public supply of electricity was controlled through state ownership and strong central planning. Generation and transmission in England and Wales (which accounts for the bulk of the UK market) was the responsibility of the CEGB and distribution was carried out by 12 regionally based local monopolies, called the area boards. All these bodies were 100 percent state-owned, responsible to the Secretary of State for Energy. The electric power supply in Scotland and Northern Ireland was also state-owned, with vertically integrated regional utilities accountable to the Secretaries of State for Scotland and Northern Ireland, respectively.

Since 1990, the UK electricity market has been undergoing a transition from domination by state-owned monopolies towards a more competitive privatized environment. The entire supply market should be open to competition by the end of 1998. During the privatization process, a financial analysis revealed that the long-term liabilities and potential unprofitability of the nuclear stations could jeopardize the success of the privatization. Subsequent to this revelation, nonnuclear (i.e., fossil fuel and hydroelectric) power generating stations and electricity distribution systems were placed in new companies that would be privatized, and the nuclear stations were retained by the government in two new companies, Nuclear Electric (NE) and Scottish Nuclear (SNL).

In 1994, the government reviewed its nuclear program to determine the future of the industry. Despite significant cost savings made by NE and SNL, it was clear that the first generation Magnox reactors would not qualify for privatization. Of the nine commercial Magnox stations (each with two reactors) commissioned between 1962 and 1971, three were shut down and in the early stages of decommissioning and the remaining lifetimes for the other six was uncertain. The second generation AGRs and the newly completed Sizewell 'B' PWR offered a much better prospect for privatization. After the review, the state-owned commercial nuclear program was reorganized as follows:

- The Magnox reactors in NE and SNL were assigned to a new company, Magnox Electric, which would stay in the state sector.

- The AGRs and PWR were retained in NE and SNL, as applicable, but the two companies were placed in a single holding company, British Energy (BE), which would be privatized.

BE was formed in December 1995 and the company was successfully privatized in July 1996. Magnox Electric remained an independent state-owned company until January 1998, when it was merged with the state-owned BNFL.

BE currently owns 14 AGRs and one PWR which were formerly owned and operated by NE and SNL. BNFL is the owner of the remaining 20 operating Magnox reactors.

Enrichment. In 1970, the UK signed the treaty of Almelo, with the Netherlands and Germany, which was aimed at promoting the sharing of technology to achieve rapid exploitation of gas centrifuge uranium enrichment technology. All three countries had earlier participated in the Eurodif study group, but withdrew after concluding that centrifuge technology offered significant advanages. The treaty was ratified in 1971, and Urenco was formed subsequently to market, administer, and coordinate production from the centrifuge plants to be constructed. Urenco enrichment plants, with a combined capacity of 4,000 MTSWU, are currently operating at three sites: Almelo, Netherlands; Capenhurst, England; and Gronau, Germany.

Uranium Fuel Fabrication. Fabrication of uranium metal fuel for Magnox reactors began at the BNFL Fuel Fabrication Plant in Springfields, which began operation in 1960. In 1995, fuel fabrication for AGR and PWR reactors began in the BNFL Oxide Fuel Facility, also in Springfields.

Reprocessing. The nuclear program in the UK has always viewed reprocessing as an integral part of the fuel cycle, and the UK has developed and operated several reprocessing plants. Magnox reactors produce several times as much spent fuel (per unit of power output) as enriched uranium fueled LWRs, and Magnox spent fuel could not be easily stored due to fuel cladding corrosion. The first British reprocessing plant, the B204 facility at Windscale, began operation in 1951, and is now referred to as the Sellafield plant. The facility was built by the Ministry of Supply to produce plutonium for military purposes. It was initially supplied with spent fuel from military reactors ("the Windscale Piles") and later on from the eight Magnox reactors at Calder Hall and Chapelcross. The maximum throughput at B204 was about 750 MT of low-burnup Magnox fuel. By the mid-1950s, the emerging civilian nuclear program made it necessary to construct a larger commercial reprocessing plant. In 1964, the new reprocessing facility, B205, began operation and B204 was shut down. B205 reprocessed domestic Magnox fuel as well as fuel from two Magnox reactors in Italy and Japan. The maximum throughput at the new B205 plant was about 1,500 MT of Magnox fuel.[23]

By the time B205 started operation, the UK nuclear power program was planning to shift from metal-fueled reactors to oxide-fueled AGRs. Additionally, a number of LWRs were beginning operation in other countries, and the prospects for developing an international market for reprocessing oxide fuels appeared promising. It was decided that an oxide fuel reprocessing capability should be provided at Sellafield. However, since the spent fuel inventories would not warrant a major plant for some time and the second reprocessing plant had spare capacity in the solvent extraction cycles, the decision was made to build only a head-end plant for oxide fuel assemblies. The choice was then whether to provide a totally new facility or to modify the B204 facility which, although shut down, was still operable. The latter route was chosen and a new head-end facility was incorporated into the plant and began operating in 1968. Because there was only a limited supply of oxide spent fuel for the B204 head-end facility, and B204 operations had to be phased with operation of the B205 facility, LWR oxide fuel reprocessing was carried out in campaigns. From 1969 to 1973, four campaigns were successfully carried out in which a total of about 90 MTU of oxide fuel was reprocessed. The B204/B205 plant had

[23] Ibid., pp. 156-158.

a maximum capacity of 300 MT of oxide fuel, and it reprocessed 113 MT of oxide fuel from power reactors (78 MT) and research reactors (35 MT), separating a total of an estimated 0.36 MT of plutonium.[24]

In 1973, during startup of the fifth oxide fuel campaign, an radioactivity release incident occurred that eventually led to the closure of the B204 head-end facility. Following this incident, BNFL decided to construct a new reprocessing plant dedicated solely to oxide fuel-the Thermal Oxide Reprocessing Plant (THORP), and B205 was thereafter solely dedicated to reprocessing Magnox fuel. By the end of 1995, some 26,800 MT of Magnox fuel had been reprocessed in B205, producing some 59 MT of separated plutonium. This fuel was primarily of UK origin but also included over 1,300 MT of Magnox fuel from an Italian reactor and 1,100 MT from the Japanese Tokai 1 reactor.[25] A major refurbishment of the B205, which was intended to enable the plant to continue operating for up to an additional 20 years, plant was carried out in 1997.

Plans for THORP were first announced in the winter of 1974-1975 as part of a large investment and development program. The project, however, was significantly delayed by public opposition that eventually led to the Windscale Public Inquiry in 1977. After the positive outcome of the inquiry, BNFL was finally given the permission to build and operate the plant. After several years of planning and design, construction of the THORP spent fuel storage pools started in 1983 on the Sellafield site. The plant was completed in February 1992 at a cost of £1.85 billion, but active commissioning was delayed because of strong opposition from the anti-nuclear lobby. Operation at THORP finally commenced in March 1994.

Since the start of operations at THORP, throughput has been gradually increased every year. Between April 1997 and March 1998, BNFL reprocessed more than 750 MTHM in THORP. Throughput is scheduled to be increased further to around 900 MTHM per year, so as to process 7,000 MTHM in total over the first 10 years of operation. Virtually all capacity for the first decade of operation has been committed in more than 40 contracts with 34 utilities in the United Kingdom, Japan, Germany, Switzerland, Spain, Sweden, Italy, Canada, and the Netherlands. About 70 percent of the capacity is for foreign fuel. To fill the domestic capacity of THORP, BE has firm reprocessing commitments for 4,800 MTU of AGR fuel. In addition, there are contracts covering the back-end management of the balance of all spent fuel discharges for the remaining lifetimes of BE’s AGRs. (These contracts include options for reprocessing and interim storage/disposal.) By 2006, THORP is expected to have separated 46 MT of plutonium, including 39 MT from foreign LWR fuels.[26] BNFL has scheduled to amortize the capital cost of the plant over the first decade of operation, after which reprocessing contract prices are expected to decrease.

[24] Ibid., pp. 156, 161.

[25] Ibid., pp. 159, 188.

[26] Ibid., pp. 161-163.

In addition to B205 and THORP plants operated by BNFL, smaller reprocessing plants, Building D1204 and D1206 located in Dounreay in northern Scotland, have operated by the United Kingdom Atomic Energy Authority (UKAEA). D1204 began operating in 1958 for reprocessing FBR and material test reactor fuel and had a capacity of 10 MTHM per year. It is used for reprocessing the spent fuel from UKAEA research projects and from the operation of two shut down FBRs at Dounreay. By December 1993, the Dounreay plants had separated an estimated 3 MT of plutonium.[27] The Dounreay reprocessing plant is expected to cease operations in 2006, at which point the FBR spent fuel backlog will have been processed.

MOX Fuel Fabrication. Two MOX fabrication plants, a demonstration plant and a larger production facility, have been developed in the UK BNFL's MOX demonstration facility began operation in November 1993 at the Sellafield site. This plant has a capacity of 8 MTHM per year and is intended to demonstrate BNFL's MOX fabrication technology. To date, the plant has performed work for Swiss, German and Japanese customers.

A commercial-scale MOX fabrication plant, the Sellafield MOX Plant (SMP), was built at the same site and began operation in 1997.[28] The SMP has a theoretical capacity of 120 MTHM per year and would be capable of fabricating fuel for most types of PWRs and BWRs. The SMP is undergoing commissioning trials, but UK government approval to start operation has not yet been received.

The UK utilities do not intend to use MOX fuel in the Magnox and AGR plants. However, the Sizewell 'B' PWR is a possible candidate for MOX fuel. BE and BNFL have established a working group to consider the technical aspects of MOX usage, but there are currently no firm commitments to use this MOX fuel in this reactor.

HLW Disposal. For disposal of HLW produced from reprocessing of UK spent fuel, a program of geological studies to determine possible sites for an underground HLW repository was carried out by the UKAEA and the Institute of Geological Sciences in the period up to 1981. Work was discontinued, partly due to the negative public reaction to this project.

ILW Disposal. In the UK, ILW is generated primarily from dismantling and reprocessing spent fuel. The waste includes primarily metal such as cladding from spent fuel assemblies, as well as smaller quantities of cement, graphite, organic materials, inorganic sludges, glass, and ceramics.[29] The radioactive content is generally not as high as HLW and heat generation is minimal with no requirement to provide for heat dissipation. ILW disposal is the responsibility of the waste management company, UK Nirex Limited (Nirex), which is jointly owned and funded by BNFL, UKAEA, BE, and the UK government.

[27] Ibid., pp. 160, 164.

[28] Ibid., p. 197.

[29] *1994 UK Radioactive Waste Inventory*; NIREX Report No. 695, DOE/RAS/96.001; May 1996.

Nirex has spent several years developing plans to construct an underground Rock Characterization Facility close to Sellafield. However, in an unexpected decision announced in March 1997, the Secretary of State for Environment rejected Nirex's formal planning application to build this facility. ILW is currently stored at the nuclear sites where it was generated, primarily at the Sellafield site. Small quantities of ILW are also stored at power stations. Since 1990, BNFL has encapsulated its ILW in a cement matrix. The drums of cement waste are then transferred into purpose-built dry stores pending final disposal once the Nirex repository is available.

LLW Disposal. Since 1959, LLW has been disposed at the 110-acre Drigg facility in northwest England, three miles from the BNFL Sellafield site. Initially, waste was disposed in unlined trenches cut into the natural boulder clay. Beginning in 1988, waste was compacted before being disposed in concrete vaults. The vaults, once full, are landscaped by an earth cap of 5 meters minimum thickness.

3.1.2 Current Status

The UKAEA and BNFL are currently the major organizations in the UK's nuclear energy industry. UKAEA is responsible for the decommissioning and liabilities associated with nuclear reactor, R&D programs, radioactive waste disposal, and nuclear fuel reprocessing in the United Kingdom. BNFL specializes in radioactive waste management, decontamination and decommissioning of outmoded facilities, and technology development and application. The following government organization also effect the United Kingdoms nuclear energy program:

- Building Research Establishment (BRE) - Helps enable companies to maximize the benefits of nuclear waste minimization, recycling, and other environmental improvements.
- Environment Agency - Regulates and conducts research on nuclear waste management and disposal and the discharge of radioactive materials into the environment.
- Institute of Oceanographic Sciences (IOS) - Models radionuclide transport in the ocean.
- Ministry of Agriculture, Fisheries, and Food (MAFF) - Regulates the management of nuclear waste prior to disposal.
- Nuclear Safety Directorate (NII) - Licenses nuclear facilities.
- United Kingdom Nirex Limited (Nirex) - Manages the R&D of a site suitable for a deep repository for LLW and ILW (to be proposed to the government); construct and operate this repository.

- National Radiological Protection Board (NRBP) - Advises the government and private organizations on radiological protection matters and standards, and conduct research to improve nuclear safety.[30]

Reactors. The 35 currently operating commercial nuclear reactors in the UK are owned and operated by BE and BNFL.

Uranium Supply. The UK has no indigenous uranium resources. Supplies are currently provided through several term contracts, with BNFL (United Kingdom) providing 25 percent, Tenex (Russia) 15 percent and ERA (Australia) 10 percent. The United Kingdom will maximize CIS-origin uranium purchases within the constraints imposed by Euratom. Most contacts include options for extension.

Fuel cycle Facilities. The major domestic operating facilities are BNFL Springfields (conversion and fuel fabrication); Urenco Capenhurst (enrichment); BNFL THORP, B205, and Dounreay (reprocessing); and BNFL Sellafield (MOX fabrication). In a recent UK radioactive waste generation projection, B205 was assumed to operate until after all UK Magnox reactors are shut down (~2008), THORP was assumed to operate until 2013, and the Springfields facilities were assumed to operate until 2030.[31]

HLW Disposal. As of April 1994, the stored HLW inventory in the UK consisted of 78 cubic meters of vitrified waste and 1,560 cubic meters of non-vitrified waste, primarily nitric acid containing fission products. The total volume after all this HLW has been vitrified is expected to be 653 cubic meters. The inventory contained an estimated 36 million terabecquerels (3.6 x 10^{19} becquerels, equal to 970 million curies.[32] The UK is not planning to develop a HLW disposal facility for several decades. The waste is currently placed in long-term storage to allow the short-lived radionuclides to decay and heat generation to decrease. In addition to domestic waste, the United Kingdom also has a responsibility for managing waste produced through overseas reprocessing contracts secured before 1976. Contracts signed after 1976 include an obligation to return waste to the overseas customers. However, under the recently approved principle of waste substitution, BNFL will be able to offer to return the overseas customer's share of radioactive waste completely in the form of HLW. This will avoid the need to ship large quantities of ILW and LLW overseas. Accordingly, this is expected to reduce the total HLW quantity to be disposed in the United Kingdom and at the same time increase the quantity of ILW and LLW that needs to be disposed. BNFL estimates the additional quantities of ILW and LLW remaining in the United Kingdom under this arrangement to be less than five percent of the total UK program.

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[30] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/unitedkingdom/factsheet.html.

[31] *1994 UK Radioactive Waste Inventory*; NIREX Report No. 695, DOE/RAS/96.001; May 1996.

[32] Ibid. One becquerel equals one nuclear disintegration per second. One curie equals about 37 billion becquerels.

ILW Disposal. As of April 1994, the stored inventory of ILW in the UK consisted of 2,180 cubic meters of conditioned (i.e., stabilized for disposal) waste and 59,300 cubic meters of unconditioned waste. When conditioned, the total volume of all this ILW is expected to be 66,100 cubic meters. This ILW contained 4 million terabecquerels, equal to about 100 million curies. About 60 percent of the inventory was in storage at Sellafield, with the rest at ten other sites, including Dounreay, Aldermaston, Harwell, and at power stations. By 1996, the inventory volume had increased to 80,000 cubic meters. An additional 70,000 cubic meters is expected to be generated by 2010.[33] Prior to disapproval of its Sellafield Rock Characterization Facility by the Secretary of State for the Environment, Nirex had intended for this project to be an important first step in constructing a full-scale repository for disposal of both ILW and LLW that would come into operation in 2012. Nirex now has to decide whether to revise the existing plans for the facility and gather new data to support its safety case or to look for a new site away from Sellafield. There is considerable uncertainty associated with the projected date of operation for the final repository.

LLW Disposal. The primary LLW disposal facility in the UK, the Drigg facility operated by NIREX, is expected to be operational until around 2050. As of 1994, nearly 1 million cubic meters of LLW had been disposed in the UK[34]

3.1.3 Current Strategy

In 1995, the UK government announced that public funding will no longer be used to build new nuclear plants. Any new development, therefore, will depend on the ability of nuclear power to compete with generation based on other fuels. At this time, no private sector generators, including BE, are willing to invest in new nuclear plants. Development of additional nuclear plants will depend on prevailing market circumstances.

[33] Ibid.

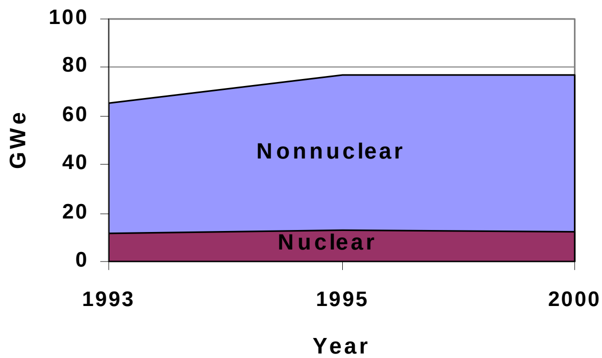
[34] Ibid.

3.2 Statistics

3.2.1 Nuclear Profile

Total nuclear power production (1996)[35]	86 TWe
Percent of total power production that is nuclear (1996)[36]	26%
Total nuclear generating capacity (1997)[37]	14 GWe
Number of operating commercial reactors[38] TOTAL Magnox AGR PWR	 35 20 14 1
Percent of world nuclear generating capacity	6%

Electric Power Capacity



Electric Power Production (1993)

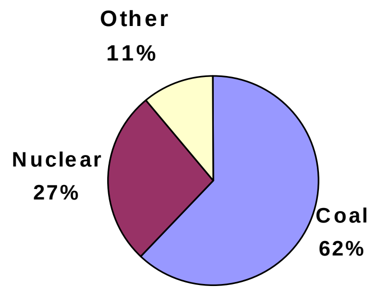


Chart data from: Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/unitedkingdom/factsheet.html.

[35] 1996 data from IAEA.

[36] Ibid.

[37] *World Nuclear Performance*. Feb. 1998. Vol 13, Issue 2.

[38] *World Nuclear Industry Handbook 1998*. Nuclear Engineering International. p. 120-127.

3.2.2 Fuel Cycle Facilities

Exhibit 3-1. Commercial Nuclear Fuel Cycle Facilities Located in the United Kingdom

Fuel Cycle Step	National Requirement (annual)	Company/Facility	Operating Period	Capacity Data (annual)
Uranium Production	2,700 MT U_3O_8	None	None	None
Conversion (U_3O_8 to UF_6)	1,800 MTU* UF_6	BNFL/Springfields	*1993 - present*	6,000 MTU (provides about 900 MTU to UK reactors)
Conversion (UF_6 to UO_2)		*BNFL/Springfields*	*1995 - present*	*710 MTU*
Conversion (U residue to UF_6)		*- /EUCF*	*1993 - present*	*65 MTU*
Enrichment	1,000 MTSWU	Urenco/Capenhurst	*1976 - present*	All 3 Urenco sites combined (in the UK, Germany, and the Netherlands) provide 750 MTSWU
Uranium Fuel Fabrication	N/A	BNFL/Springfields	1960 - present	1,300 MTU Magnox, 300 MTU PWR, and 260 MTU AGR
		AEA/Dounreay	*1959 - present*	*1,500 elements of research reactor fuel*
Reprocessing	N/A	BNFL/Sellafield B204	1950 - 1973	*750 MT Magnox 300 MT oxide*
		BNFL/Sellafield B205	1964 - present	*1,500 MTHM*
		BNFL/Sellafield THORP	*1994 - present*	750 MTHM (1997) 900 MTHM (in a few years) PWR & BWR fuel
		UKAEA/Dounreay	*1980* - present (to close in 2006)	10 MTHM MOX fuel
MOX Fuel Fabrication	N/A	BNFL/Sellafield MOX Demonstration Facility	*1983 - present*	*8 MTHM*
		BNFL/Sellafield MOX Plant	*1998 - present*	*120 MTHM MOX*
ILW & LLW Disposal	N/A	BNFL/Sellafield Drigg	1959 - 2050	
HLW Treatment	N/A	BNFL/Sellafield	1990 - present	Vitrifies 250-300 MT glass[39]

* 1,800 MTU is the conversion requirement for the BNFL/BE reactors and does not include conversion needed to produce Magnox fuel.
** Italicized data from World Nuclear Industry Handbook 1998. Nuclear Engineering International. p. 120-127.

[39] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/unitedkingdom/factsheet.html.

Exhibit 3-2. Non-Domestic Fuel Cycle Facilities Supplying the United Kingdom

Fuel Cycle Step	Location	Company/Nationality	Supplied to UK
Uranium Production	No info	BNFL	25% of national requirement
	Russia	Tenex	15% of national requirement
	Australia	ERA	10% of national requirement
Conversion (U_3O_8 to UF_6)	Russia	Tenex	30% of BE’s requirements
Enrichment	Netherlands (Almelo), Germany (Gronau)	Urenco/UK, Netherlands, Germany	All Urenco sites combined provide 75% of national requirement
	Russia	Tenex	25% of national requirement

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4.0 Germany

4.1 Nuclear Program

4.1.1 History to Date

The commercial nuclear program in Germany started later than the corresponding British and French programs due to a post-World War II nuclear research ban that lasted until 1955. The German Atomic Law, governing the peaceful use of nuclear power in Germany, was enacted in 1959. Changes to German nuclear policy require revision to this law and its associated decree laws. The most recent important revision occurred in 1994. Until then, the Atomic Law had mandated a closed fuel cycle (i.e., reprocessing of spent fuel), but the 1994 revision allowed direct disposal of spent fuel as an alternative back-end management strategy for German utilities. German utilities originally supported spent fuel reprocessing with the use of recovered plutonium in FBRs.

Reactors. By the late 1950s, Germany concluded that the United States held the advantage in commercial nuclear power technologies. In 1958, Germany ordered its first reactor, the Kahl boiling-water reactor (BWR), from General Electric (GE), which entered operation in 1962. After reunification, Germany inherited six Russian-designed reactors from the German Democratic Republic (GDR). All have been permanently shutdown for safety reasons.

Germany also participated in two fast breeder reactor projects, including its own SNR-300 and the French Superphenix FBR project. Construction of the SNR-300 FBR at Kalkar was completed, but the project terminated in 1991 and the reactor never started up. The application for the operating license was withdrawn because of continuous political and licensing disputes.

Uranium Production. Germany has only small reserves of uranium in the western part of the country, and the large mining operations in the former GDR have been closed for several years. Only small quantities of uranium are recovered in the ongoing restoration work. As a result, Germany purchases uranium from other countries.

Conversion. Historically and currently, Germany has no involvement in the conversion of U_3O_8 to UF_6 Germany either procures conversion services from non-domestic sources or UF_6 is purchased on the world market.

Enrichment. In March 1970, the governments of Germany, the Netherlands, and the United Kingdom signed the treaty of Almelo to promote technology sharing to achieve rapid exploitation of centrifuge enrichment. All three countries had participated in the Eurodif study group that examined gaseous diffusion enrichment technology, but withdrew after concluding that centrifuge technology offered significant advantages. In 1971 the Almelo Treaty was ratified, and Urenco, Ltd. was established to market, administer, and coordinate production of enriched UF_6 from planned centrifuge plants. One of Urenco's centrifuge enrichment plants was constructed in Gronau and began operation in 1995. Germany also developed jet nozzle enrichment technology, but sold this technology to Brazil after concluding that it was not competitive with centrifuge technology.

Uranium Fuel Fabrication. PWR and BWR fuel fabrication capabilities developed separately from each other in Germany and proceeded along different paths. For BWR fuel, AEG and GE founded a fuel fabrication facility at Karlstein. For PWR fuel, Siemens developed fabrication technology at Hanau. In the late 1960s, the industry consolidated, and various fuel fabrication activities in Germany were integrated into Siemens/KWU, which was the major reactor supplier for German utilities. The consolidation was completed in the late 1980s. Another uranium fuel fabrication facility operates in Lingen.

Reprocessing. One of Germany's major chemical companies proposed a pilot reprocessing plant to the German government in 1960. In 1963, the Ministry for Scientific Research commissioned a detailed design study for a reprocessing plant, and by the end of 1971 Wiederaufarbeitungs Anlange Karlsruhe (WAK), a 35-MT-capacity pilot plant, was in operation. It reprocessed a total of 208 MT oxide fuel, including nearly 100 MT of German commercial reactor fuel, before it closed permanently in 1990.[40]

The German utilities planned to construct a 350 MTHM per year commercial reprocessing plant at Wackersdorf in Bavaria. Although the government endorsed the plan, it was clear from the outset that it would not provide funding. In 1989, after extensive design work had been completed and construction had started, the project was cancelled. The utilities realized that Wackersdorf would ultimately be too expensive, and political problems associated with the plant were growing. The utilities convinced the government to accept that the reprocessing requirement in the Atomic Law could be met by securing additional reprocessing commitments outside Germany. The German utilities then entered into the post-baseload reprocessing commitments with BNFL (UK) and Cogema (France).

MOX Fuel Fabrication. MOX fuel fabrication, primarily for the FBR programs in Europe, was developed at the Karlsruhe research center between the mid-1960s and 1972. Following industry consolidation, these activities were conducted at the Hanau site. A MOX fuel demonstration plant with a capacity of 35 MTHM per year was constructed at Hanau and operated by Siemens from 1972 to 1991, producing a total of nearly 160 MT of MOX fuel, when operation was interrupted due to a contamination incident.[41] The facility never re-opened. A full-scale production facility with an annual capacity of 120 MTHM per year was also built at the Hanau site, but the state government and licensing authorities prevented it from entering operation. In 1995, Siemens and the German utilities decided to abandon this project.

[40] *Plutonium and Highly Enriched Uranium 1996 World Inventories, Capabilities, and Policies*; D. Albright, F. Berkhout, and W. Walker; Stockholm International Peace Research Institute; Oxford University Press; 1997. pp. 156, 178.

[41] Ibid.

LLW & ILW Disposal. The Morsleben repository is located in the federal state of Saxony-Anhalt. At the site, potassium was mined until the early twenties. Thereafter, rock salt mining went on until 1969, both leaving open cavities with a volume of approximately 10 million cubic meters. In 1970, the nuclear power plant operator of the former German Democratic Republic bought the mine to convert it into a LLW and ILW repository. After a licensing procedure, waste disposal started in 1978 using rock cavities below the 500 meter horizon for waste emplacement. Morsleben became a Federal Facility following German reunification; DBE was then contracted to operate the site. As of end of 1997, the radioactive waste disposed at Morsleben amounted to 32,000 cubic meters radioactive waste and 6,600 sealed radiation sources.[42]

The Morsleben repository operation license, originally valid until June 30, 2000, has been extended until 2005. The established waste volume and radioactivity limits for the facility are 55,000 cubic meters of waste, 1.0×10^{16} bequerels for beta and gamma-emitting nuclides and 1.0×10^{13} bequerels for alpha-emitters.

In 1976, the newly closed Konrad iron mine in Lower Saxony was selected for investigation as a possible radioactive waste repository because of its depth, dryness, and isolation from shallow groundwater by clayish overlying rock. Results of an extensive survey and evaluation program led in 1982 to a positive statement regarding the site suitability to host a radioactive waste repository. According to the license application, Konrad will be a repository for waste with negligible decay heat. Approximately 90 percent of the waste volume arising in Germany belongs to this category. The radioactivity limits set for the facility are 5.0×10^{18} bequerels of beta-gamma activity and 1.5×10^{17} of alpha activity. The planned repository consists of six emplacement fields at different levels between 800 and 1,300 meters in depth with a net disposal capacity of approximately 650,000 cubic meters. The license for Konrad is expected soon, shortly after which the site operator, DBE, will begin construction of the supporting surface facilities. Conversion of the mine into a disposal facility is expected to require about four years.[43]

HLW and Spent Fuel Management. Germany constructed centralized away-from-reactor dry storage facilities at Gorleben and Ahaus. Spent fuel shipments to these facilities have been carried out but were accompanied by massive anti-nuclear demonstrations. A salt dome near the village of Gorleben also is being evaluated as a potential repository for HLW.

4.1.2 Current Status

Nine utilities currently operate 20 reactors, many of which operate on partial MOX cores. One reactor, Mülheim Kärlich, is currently off-line due to a long-standing political licensing dispute between the owner-RWE Energie-and the state government of Rheinland Pfalz.

[42] http://www.dbe.de

[43] Ibid.

All electric utilities and nuclear fuel cycle companies in Germany are private enterprises; they are not controlled by federal or state governments, although in some cases a state may be a shareholder. Contributions to nuclear power by federal and state governments have been limited to research and development activities in reactor and fuel cycle technology. The federal government has responsibility for nuclear waste disposal programs, while utilities pay most of the costs for final waste disposal.

The German government organization involved in the regulation, monitoring, and support of the German nuclear energy industry are:

- Federal Ministry for Education, Science, Research, and Technology (BMBF) - regulates and provides research and development programs for fuel cycle and nuclear waste management and disposal activities.

- Federal Ministry for Economics (BMWi) - decides national energy policy.

- Federal Institute for Geosciences and Natural Resources (BGR) - responsible to BMWi for all geological/geotechnical aspects related to the planning, construction, and operation of a final repository for radioactive wastes.

- Federal Ministry of Finance (BMF) - oversees the decommissioning of the six Russian built PWRs in the former GDR.

- Federal Ministry of Environment, Nature conservation and Nuclear Safety (BMU) - responsible for storage, transportation, and disposal of radioactive wastes, as well as federal standards for nuclear safety and radiation protection and the supervision of state licensing procedures (the state government are responsible for the licensing of nuclear facilities and repositories).[44]

Germany's 1998 UF_6 conversion requirement is about 3,500 MTU. The primary suppliers are Cameco (Canada-25 percent), BNFL (United Kingdom-25 percent) and COMURHEX (France-25 percent). The German utilities also purchase UF_6 product on the world market to meet some of the requirements of the reactor program.

Currently Urenco operates centrifuge enrichment facilities at three sites-Almelo, Netherlands; Capenhurst, United Kingdom; and Gronau, Germany-with combined annual capacity of 4,000 MTSWU. The current German annual uranium enrichment requirement is about 1,900 MTSWU. About 60 percent of the 1998 German enrichment requirement is supplied by Urenco. Other suppliers include Eurodif (France-15 percent) and Tenex (Russia-15 percent).

The only currently operating uranium fuel fabrication facility in Germany is a 650-MTHM facility in Lingen.

[44] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/germany/factsheet.html.

Germany's 1998 BWR fuel fabrication requirement is about 140 MTHM and the corresponding PWR fuel fabrication requirement is about 340 MTHM. Approximately 60 percent of German utility commitments for BWR fabrication services are contracted to Siemens (Germany). ABB (Sweden) provides about 25 percent and GE (United States) about 10 percent. PWR fabrication services are contracted to Siemens (70 percent), ABB (10 percent), and Fragema (France-5 percent).

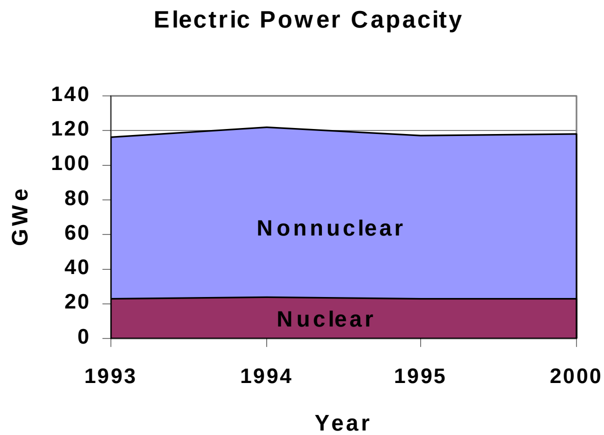
4.1.3 Current Strategy

There are no immediate plans for additional nuclear power plants in Germany, but research and development into advanced reactor types (EPR and SWR1000) is ongoing. Licensing requirements for future reactors are being revised to provide for the generic licensing of specific reactor types regardless of where the reactor will be deployed. This gives the German utilities the chance to plan new reactors without immediately facing public opposition from anti-nuclear groups.

4.2 Statistics

4.2.1 Nuclear Profile (1997 Data)

Total nuclear power production (1996)[45]	152 TWh
Percent of total power production that is nuclear (1996)[46]	30%
Total nuclear generating capacity (1997)[47]	22 GWe
Number of operating commercial reactors[48] TOTAL PWR BWR	 19 13 6
Percent of world nuclear generating capacity	9%



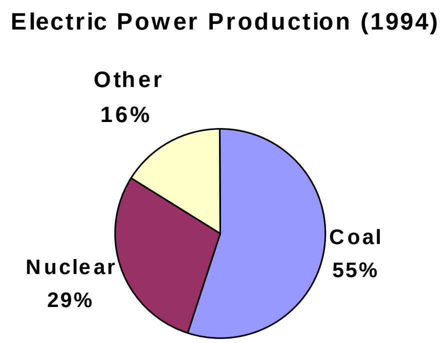


Chart data from: Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/germany/factsheet.html.

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[45] 1996 data from IAEA.

[46] Ibid.

[47] *World Nuclear Performance*. February 1998. Volume 13, Issue2.

[48] *World Nuclear Industry Handbook 1998*. Nuclear Engineering International.

4.2.2 Fuel Cycle Facilities

Exhibit 4-1. Commercial Nuclear Fuel Cycle Facilities Located in Germany

Fuel Cycle Step	National Requirement (annual)	Company/Facility	Operating Period	Capacity Data (annual)
Uranium Production	3,800 MT U_3O_8	*Gew Brunhilde/ Ellweiler*	*1989 - Shut Down*	*125 MT*
Conversion	3,500 MTU	None		
Enrichment	1,900 MTSWU	*Urenco/Gronau*	*1985 - present*	*800 MTU*
		Urenco/Julich	- present	
Uranium Fuel Fabrication	BWRs - 140 MT PWRs - 340 MT	Siemens/Lingen	Late 1980's - present	650 MTHM
		AEG & GE/Karlstein		(BWR fuel)
		NUKEM/Wolfgang	- present	
		Siemens/Hanau	- present	(PWR fuel)
Reprocessing	N/A	WAK/Karlsruhe	1971 - 1991	*40 MTHM*
		Wackersdorf	Partially constructed, then canceled	350 MTHM
MOX Fuel Fabrication	N/A	/Karlsruhe	- present	
		Siemens/Hanau	*1963* - 1991	35 MTHM FBR/LWR
		Siemens/Hanau	*Suspended Indefintely*	120 MTHM BWR/PWR
		Siemens/Hanau	*1969 - 1995*	*700 MTHM*
LLW Disposal	N/A	Morlesben	1978 - present	55,000 m^3
HLW Management	N/A	VKTA/EKR	1997 - present	SNF storage
		GNS (BZA)/Ahaus	1992 - present	*3,960 MTHM storage*
		GNS (BLG)/Groleben	1995 - present	*1,500 MTHM storage*

* Italicized data from World Nuclear Industry Handbook 1998. Nuclear Engineering International. p. 120-127.

Exhibit 4-2. Non-Domestic Fuel Cycle Facilities Supplying Germany

Fuel Cycle Step	Location	Company	Supplied to Germany
Uranium Production	No information	Urangesellschaft	30% of national requirement
	Russia	Tenex	15% of national requirement
	Canada	Cameco	10% of national requirement
Conversion (U_3O_8 to UF_6)	United Kingdom	BNFL	25% of national requirement
	Canada	Cameco	25% of national requirement
	Canada	COMUREX	25% of national requirement
Enrichment	Almelo, Netherlands, and Capenhurst, United Kingdom	Urenco	All Urenco facilities combined - 60% of national requirement
	Russia	Tenex	15% of national requirement
	France	Eurodif	15% of national requirement
Uranium Fuel Fabrication	Sweden	ABB	25% for BWRs, 10% for PWRs
	France	Fragema	10% for BWRs, 5% for PWRs
Reprocessing	THORP, United Kingdom	BNFL	
	UP3, France	COGEMA	
MOX Fuel Fabrication	Dessel	Belgonucleaire	

5.0 Russia

5.1 Nuclear Program

5.1.1 History to Date

In response to what it considered to be the threat presented by the nuclear weapons capability of the United States, the Soviet Union, immediately following the second world war, began a program to develop nuclear weapons. The development of a nuclear power program, which began in the 1950s, was intended to take advantage of nuclear technology by producing cheap electricity for industrial and domestic use.

The first civilian nuclear power plant in Russia was commissioned in 1964. This plant proved successful and, in the 1970s, the Soviet Union developed plans for expanding its nuclear power program. During the 1980s, nuclear power plant construction reached its peak as 15 new plants were commissioned. According to the plan being implemented at that time, approximately 200 GWe nuclear generating capacity was due to be in service by 2000 with fuel cycle plant capacities being expanded to supply the increasing number of reactors.

Following the Chernobyl accident in 1986, however, the nuclear expansion program was put on hold while the myriad of safety issues arising from the accident were addressed. Then, the collapse of the Soviet economy at the end of the 1980s precluded significant investment in major projects in any sector of industry and construction of new nuclear facilities stopped altogether. Today, the countries of the former Soviet Union (FSU) have a total of 35 GWe operational nuclear generating capacity, of which approximately 20 GWe is in Russia. Since the collapse of the Soviet Union, Russia's Ministry of Atomic Power (Minatom) has been responsible for managing the nuclear facilities that it inherited from the Soviet Union.

In the seven years since its formation, Minatom has been preoccupied with its own survival and has had little funding available for investment in plant construction, or even in equipment maintenance. As a consequence, production at existing facilities continues to decline and a number of nuclear power plants and fuel cycle plants remain part completed, even though construction started a decade ago.

Consistent with the philosophical separation of the East and West, the Soviet Union developed its own reactor types. These reactor types were quite different from the designs developed in the West. The first reactor type applied to power production was the VVER-440 commissioned at Novovoronezh in 1964. The VVER-440 design is a PWR, although vastly different in design from the Western PWR. The next reactor design was the RBMK-1000, a graphite-moderated, channel-type BWR, which bears very little similarity to the Western BWR. The first RBMK-1000 was commissioned at Leningrad in 1974, after which 14 similar units were commissioned in Russia and Ukraine. The third Soviet reactor type is the VVER-1000, also a PWR. The mainstay of the new Russian reactor construction program being planned by Minatom is the VVER-640, an enhanced safety, natural-circulation variant of the VVER-1000 design. The fourth reactor type constructed by the Soviet Union was the fast reactor or BN type, of which a family of three models was designed.

Russia historically has operated one major reprocessing center for commercial power reactor fuel. Since 1976, the RT1 facility in Chelyabinsk has reprocessed commercial oxide fuel from VVER-440 and VVER-210 reactors. While the plutonium from this generally has not been recycled, the reprocessed uranium has been recycled and reused in fuel for Soviet RBMK, BN-350, and BN600 reactors. From 1956 to 1976, RT1 was used to reprocess fuel from the Soviet plutonium production reactors. By the end of 1993, and estimated 3,400 MT of power reactor fuel had been reprocessed in RT1, producing an estimated 26 MT of plutonium. Russia has no plans to reprocess the spent fuel from RBMK reactors.[49]

A second reprocessing plant, RT2 in Krasnoyarsk, is currently under construction. Intended for reprocessing fuel from VVER-1000 reactors, this facility may not be completed for some time. A spent fuel storage basin for the VVER-1000 fuel has been in operation near the RT2 facility since 1985.

5.1.2 Current Status

The Russian nuclear industry remains totally government owned, although the current Russian government is encouraging all ministries, including Minatom, to privatize industry where possible. The first step in this direction would be to establish internal markets to allow commercial trading between the various parts of Russia's nuclear industry. To date, little progress has been made in this direction. Most prices are still determined according to calculation methods established during the Soviet era, which bear little relationship to cost and leave little opportunity for making a profit.

While it would be possible for Minatom to privatize some of its activities, there are restrictions on foreign ownership and the recent decline in productivity makes minority shareholding unattractive to external investors. Until commercial electric power markets are established, operating reactors will probably not attract investors.

5.1.3 Current Strategy

The Russian government has been consistently pro-nuclear since the collapse of the Soviet Union. While there is a growing anti-nuclear lobby, it suffers from two problems - (1) it has an image of being largely Western funded and (2) if successful, the anti-nuclear lobby would reduce the number of jobs in Russia's nuclear industry - neither of which wins it support in the communist-dominated Duma or with the general Russian public, particularly in the locality of the nuclear plants.

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[49] *Plutonium and Highly Enriched Uranium 1996 World Inventories, Capabilities, and Policies*; D. Albright, F. Berkhout, and W. Walker; Stockholm International Peace Research Institute; Oxford University Press; 1997. pp. 156, 173.

Russian nuclear policy is to pursue the closed fuel cycle, including reprocessing and recycling uranium and plutonium. Since the collapse of the Soviet Union, only one new nuclear power plant has been commissioned (Balakovo unit 4) and no new construction has started. Nonetheless, Minatom has plans to complete four new plants by 2010. Completion of the RT-2 reprocessing plant at Krasnoyarsk is included in Minatom's plans, although it is likely to be completed no sooner than 2010. In addition to the RT-2, three RBMK reactors are scheduled for completion this decade, but this schedule will probably not be met.

A significant problem facing the Russian nuclear industry is a uranium shortage. The best uranium deposits identified in the Soviet Union are outside of Russia and, consequently, most of the uranium production capacity operating in the Soviet Union in 1991 passed to Kazakstan, Uzbekistan, and Ukraine. The only production facility operating in Russia at that time was at Priargunsky, near the city of Krasnokamensk in eastern Siberia. This remains the only operating uranium production site in Russia. Priargunsky production is extremely expensive, in part because the ore is of low quality and the operations require deep underground mining.

Faced with serious financial problems following the cutbacks in government funding, Minatom has not funded the maintenance program needed at Priargunsky. As a consequence, production has fallen below the level needed to meet domestic power station demand and is only approximately one-third of the quantity needed to meet Minatom's total commitments, including export contracts. The difference, to date, has been met from the national inventory, although indications are that this inventory has been so far reduced that it will only be able to make up the production shortfall for the next few years.

Following the collapse of the Soviet Union, Russia wanted to continue to be involved in uranium production and the new owner countries would have been willing to continue to supply Russia. However, following the political changes, there was no established basis for trading with these countries and negotiations for purchasing or supplying nuclear materials and services became buried in the negotiation of wider agreements that included barter payments and the cancellation of unrelated debt. Moreover, the uranium producers in Ukraine, Kazakstan and Uzbekistan have been able to sell their uranium on the world markets for hard currency, which made barter trade with Russia unattractive.

In the next few years, Russia may face problems meeting domestic power plant requirements. There are several options open to Minatom to make up the shortfall, the two most likely being increased re-enrichment of tails and re-importation of uranium under a Russia-U.S. highly enriched uranium agreement. However, both of these would reduce potential foreign earnings. Tails re-enrichment would require the use of enrichment plant capacity currently allocated to meeting export requirements. Re-importation of uranium from the United States would reduce potential sales to other countries. In the longer term, Minatom is planning to develop three new production sites using less expensive in-situ leach technology, although significant funding to develop these sites is not yet available.

5.2 Statistics

5.2.1 Nuclear Profile

Total nuclear power production (1996)[50]	108 TWh
Percent of total power production the is nuclear (1996)[51]	13%
Total nuclear generating capacity Russia[52] Former Soviet Union	 20 GWe 35 GWe
Number of operating commercial reactors[53] TOTAL VVER RBMK FBR Other	 29 13 11 1 4
Percent of world nuclear generating capacity	8%

[50] 1996 data from IAEA.

[51] Ibid.

[52] *World Nuclear Performance*. February 1998. Volume 13, Issue 2.

[53] *World Nuclear Industry Handbook 1998*. Nuclear Engineering International.

5.2.3 Fuel Cycle Facilities

Exhibit 5-1. Commercial Nuclear Fuel Cycle Facilities Located in Russia

Fuel Cycle Step	National Requirement (annual)	Company/Facility	Operating Period	Capacity Data (annual)
Uranium Mining	7,300 MT U_3O_8	Minatom/Priargunsky	- present	4,000 MT
Conversion (U_3O_8 to UF_6)	6,400 MTU	*Minatom/Angarsk*	*1965 - present*	*18,700 MTU*
Conversion (RepU to UF_6)		*Minatom/Tomsk*	*- present*	*No information*
Conversion (UF_6 to UO_2)	No information	*Minatom/Elektrostal*	*- present*	*700 MTSWU*
Enrichment	2,200 MTSWU	*Minatom/Ekaterinburg*	*1949 - present*	*9,000 MTSWU*
		Minatom/Tomsk	*1950's - present*	*3,000 MTSWU*
		Minatom/Krasnoyarsk	*1964 - present*	*5,000 MTSWU*
		Minatom/Angarsk	*- present*	*2,000 MTSWU*
Uranium Fuel Fabrication	LWR - 190 MTHM	*/Chelyabinsk*	*- present*	*300 kg FBR*
		Masinostroitdny/Elektrostat	*- present*	*700 MT VVER-440* *1000 MT VVER-1000* *570 MT RBMK* *35 MT FBR*
		/Novosibirsk	- present	
Reprocessing	N/A	Minatom/Chelyabinsk RT1	*1976 - present*	VVER-440 400 MTU
		Mining and Chemical Combine/Krasnoyarsk RT2	*Under construction*	*1500 MTU VVER - 1000*
		Sibkhimmbinat/Tomsk	*- present*	
MOX Fuel Fabrication	N/A	*Masinostroitdny/Chelyabinsk*	*Under construction*	*FBR*
		Masinostroitdny/Krasnoyarsk	*Planned*	*VVER*
LLW Disposal				
HLW Storage	N/A	Min Chem Comb/Krasnoyarsk	1985 - present	6000 MT
		Mayak/Chelyabinsk	1976 - present	No information

* Italicized data from *World Nuclear Industry Handbook 1998*. Nuclear Engineering International. p. 120-127.

Exhibit 5-2. Other Fuel Cycle Facilities Supplying the Russians

Fuel Cycle Step	Location	Company/Nationality	Operating Period	Supplied to Russia
Russia is self-sufficient in meeting its nuclear fuel cycle supply needs.				

6.0 South Korea

6.1 Nuclear Program

6.1.1 History to Date

With scarce energy resources, South Korea has viewed nuclear power as a reliable energy source to improve the energy supply structure of the country and satisfy the increasing energy demand caused by the country's economic development. In 1958, South Korea enacted the Atomic Energy Act to set the national policies of its nuclear program and, in 1959, established the Office of Atomic Energy to serve as the central government agency in charge of developing South Korea's nuclear energy program. Notwithstanding these actions, in the 1960s, South Korea took a conservative approach in developing its nuclear technology.

This approach changed in the 1970s with the availability of commercial reactors from Western suppliers, and the South Korean government began to move more aggressively, enacting a long-term energy plan that included installing nuclear capacity to supply up to 40 percent of the electric demand by 2000. To achieve this goal, the government devised a four-step approach to pursue its nuclear power program and increase technological self-sufficiency, using domestic capability whenever possible:

Step	Objective	Reactors
1	Orchestrate the turnkey installation of nuclear facilities from foreign suppliers.	Orders of Kori 1 and 2 units, and Wolsong unit 1
2	Develop indigenous manufacturing capability to enable the installation of nuclear facilities utilizing foreign contractors.	Kori 3 and 4 units; Yonggwang 1 and 2 units; and Ulchin 1 and 2 units
3	Attain domestic capability for the construction of new facilities.	Yonggwang 3 and 4 units
4	Develop a standard design and construction capability for building its own nuclear power plants.	Korean Standard Nuclear Power Plants (KSNP); Ulchin 3 and 4 units

This approach also facilitated standardization of South Korea’s nuclear power stations. The first step included using foreign suppliers (Westinghouse and AECL) to install three 600-MWe reactors. These three plants (two 600-MWe PWRs and one 600-MWe pressurized heavy-water reactor [PHWR]) were built on a turnkey basis in which the contractors had overall responsibility for the construction, tests, and startup operation of the plants. The second phase of the program included 900-MWe-class reactors that were built under the owner's responsibility. In the third phase, however, major efforts were concentrated on the maximum participation of South Korean companies. The third step of the nuclear power program also was successful in that the project was financed with a low capital cost, had a short construction period, and demonstrated significant improvements in plant operation and safety.

In the early stages of program development, the Korea Atomic Energy Research Institute (KAERI) operated two Training Research and Isotope Production General Atomics (TRIGA) reactors located in suburban Seoul. The rapid expansion of South Korea's nuclear power program in early 1980 required a new research reactor with intensive neutron sources to support nuclear R&D activities and medical and industrial applications of radioisotopes. To meet the requirement, KAERI developed the 30 MW Korea Multipurpose Research Reactor (KMRR) with capabilities of nuclear fuel in-pile testing, production of key radioisotopes, neutron activation analysis, neutron beam scattering, radiography, and other basic research. The new KMRR used fuel developed by the United States as a part of the Reduced Enrichment in Research and Test Reactors Program.

In 1992, as its electric power consumption continued to increase, the South Korean government announced a 10-year nuclear energy research and development program to achieve nuclear technological self-reliance. In 1994, the government reaffirmed its commitment to nuclear energy by establishing a long-term nuclear policy aiming towards 2030.

Reactors. South Korea's commercial program uses both light- and heavy-water reactors (LWRs and HWRs).

The first South Korean nuclear power reactor, Kori-1, a 600-MWe Westinghouse PWR, started commercial operation in 1978. The Kori site now has four units, all supplied by Westinghouse, including Kori 1, an additional 600-MWe unit (Kori 2) and two 900-MWe units (Kori 3 and 4). The Yonggwang site has two 900-MWe Westinghouse units of the same design as Kori 3 and 4.

The HWR units are located at the Wolsong site where three units are in commercial operation and a fourth is in the final construction stages. Testing of Wolsong 4 should be complete in June 1999, at which time the unit will be declared commercial.

In the 1980s, South Korea began to look for a technology transfer program that would include reactor design and the infrastructure required to produce the major components in South Korea. Ultimately, ABB-Combustion Engineering won the contract for the technology transfer program. As a result of the ABB-CE program, the Yonggwang-3 and -4 reactors are based on the ABB design, and are now referred to as the Korean Standard Nuclear Power Plant (KSNPP).

Fuel Cycle Facilities. The Korea Nuclear Fuel Company Ltd. (KNFC) was established in 1982. In September 1986, the South Korean Ministry of Science and Technology granted it permission to fabricate nuclear materials, and in November 1986, KNFC began construction of a PWR fuel fabrication plant with a capacity of 200 MTU. The Taejon fabrication facility began production of PWR fuel in January 1989 and made its first PWR fuel shipment in July 1989.

In December 1987, construction began on a uranium dioxide reconversion (UO_2-to-UF_6) plant. Commercial UO_2 reconversion began in March 1990.

KNFC established a fuel technology center in January 1992.

In December 1994, South Korea started construction on a second fuel manufacturing facility with a capacity of 750 MTU (350 MTU PWR fuel and 400 MTU PHWR fuel). Commercial operation of the new fuel manufacturing facility began in January 1998, and the plant made its first shipment of South Korean-produced PHWR fuel in July 1998.

Korea Electric Power Company (KEPCO) is currently obligated to procure all of its fabrication services domestically and, as a result, the KNFC plant supplies all of South Korea's fabrication needs for both LWRs and HWRs. This obligation is scheduled to expire at the beginning of 2001, after which KEPCO may solicit international bids in order to leverage KNFC's prices downward.

There are no facilities in South Korea for the back end of the fuel cycle. KEPCO had expressed interest in reprocessing, but recently abandoned attempts to convince the United States to allow South Korea to export spent fuel to France for reprocessing. KEPCO's Nuclear Environment Technical Institute (NETEC) is searching for a suitable location for interim storage of spent fuel. NETEC is also searching for a suitable repository for spent fuel and high-level waste.

6.1.2 Current Status

KEPCO is the largest electricity producer in South Korea and is the only one owned by the government. The non-nuclear assets of KEPCO are scheduled for privatization, but the nuclear generating assets will remain government-owned. KEPCO has several subsidiary companies or owns the majority of the shares in several companies important to South Korea's electric industry. Among these are Korea Nuclear Fuels Corporation (KNFC-96.4 percent KEPCO owned), Korea Electric Power Research Institute (KEPRI-100 percent), Korea Heavy Industries and Construction Co. (KHIC or Hanjung-40.5 percent), and Korea Power Engineering (KOPEC-97.9 percent).

In spite of the current economic problems in South Korea and East Asia, KEPCO still maintains a relatively ambitious reactor construction program, although construction of Uljin 5 and 6 has been slowed down. KEPCO's public plans call for a total of 27 units in operation by 2010, which appears very ambitious considering the weakness of both the South Korean economy and its currency. The South Koreans cite the currency situation as a reason for needing nuclear power. While this may be true with respect to the fuel supply for the operating units, it does not make economic sense to continue to build when electric power demand is decreasing.

South Korea obtains all uranium supplies, conversion, and enrichment services on international markets.

Key government organizations in the South Korean nuclear power industry:

- Ministry of Trade, Industry and Energy (MOTIE) - head government agency in power development and utilization.

- Ministry of Science and Technology (MOST) - authority for all scientific and technological efforts in South Korea

- Atomic Energy Commission (AEC) - makes policy decisions with regards to nuclear energy, as well as R&D planning for nuclear energy and fuel.

- Electric Power Bureau (EPB) - manages nuclear fuel acquisition and establishes plans and policies on energy and resources.

- Korea Atomic Energy Research Institute (KAERI) - develops reactor engineering and nuclear fuel cycle technology and assist in establishing nuclear regulatory and licensing policy.

- KEPCO - operates all nuclear power plants in South Korea.

A number of government funded institutes aid in the research and development of nuclear energy technology:

- Korea Advanced Institute of Science and Technology (KAIST)
- Korea Institute of Energy Research (KIER)
- Korea Institute of Nuclear Safety Technology (KINS)[54]
- Korea Institute of Geology, Mining and Materials (KIGAM)[55]

6.1.3 Current Strategy

In 1994, the government reaffirmed its commitment to nuclear energy by establishing a long-term nuclear policy aiming towards 2030. In the long term, the South Korean government plans to use nuclear energy as a means to strengthen the country's energy infrastructure. This will be achieved by generating a major portion (40 percent) of its electricity through nuclear power by 2010. In addition, this policy confirmed South Korea's plan in establishing a self-supporting nuclear reactor technology program and possibly creating a viable export business.

[54] KINS acts as an independent regulatory organization to develop technical standards for nuclear safety.

[55] http://etd.pnl.gov:2080/fac/southkorea/factsheet.html.

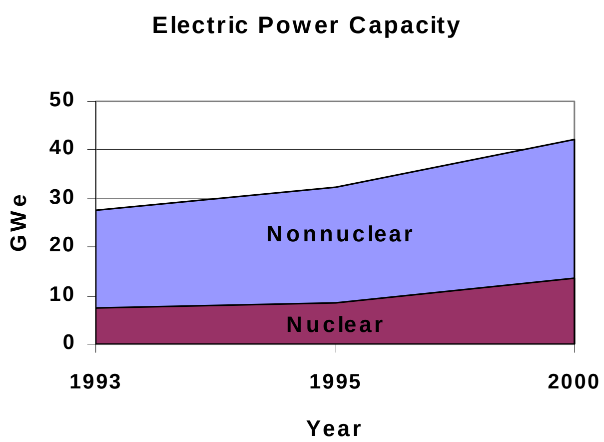
The current strategy of the South Korean nuclear program is summarized in the following table:

Topic	Policy
National Energy Policy	Continue expansion of the national energy capacity to satisfy demand. Minimize reliance on foreign oil supply by expanding the nuclear power program with domestic capability. Develop fast breeder reactor technology as a long-term program.
Fuel Cycle Policy	Develop long-term contracts with fuel suppliers. Acquire foreign uranium resources to minimize reliance on foreign suppliers. Achieve domestic fuel fabrication capability to meet domestic demand for PHWR and PWR fuel. Proceed with an open-ended fuel cycle strategy until the feasibility of reprocessing and recycling of plutonium is proved.
Waste Management Strategy	Develop a radioactive waste management program. Select a site as a permanent waste storage facility. Complete a radioactive waste management complex, including a low-level waste repository by 2008. Construct an interim spent fuel facility by 2010.

6.2 Statistics

6.2.1 Nuclear Profile

Total nuclear power production (1996)[56]	73TWh
Percent of total power production that is nuclear (1996)[57]	35%
Total nuclear generating capacity (1997)[58]	10 GWe
Percent of total generating capacity that is nuclear	30%
Number of operating commercial reactors[59] TOTAL PWR RBMK	 13 11 2
Percent of world nuclear generating capacity	4%



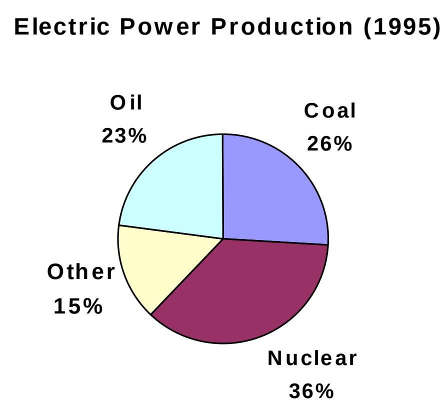


Chart data from: Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/southkorea/factsheet.html.

[56] 1996 data from IAEA.

[57] Ibid.

[58] *World Nuclear Performance*. February 1998. Volume 13, Issue 2.

[59] *World Nuclear Industry Handbook 1998*. Nuclear Engineering International.

6.2.2 Fuel Cycle Facilities

Exhibit 6-1. Commercial Nuclear Fuel Cycle Facilities Located in South Korea

Fuel Cycle Step	National Requirement (annual)	Company/Facility	Operating Period	Capacity Data (annual)
Uranium Production	2,900 MT U_3O_8	None		
Conversion (U_3O_8 to UF_6)	2,200 MTU	None		
Enrichment	1,100 MTSWU	None		
Uranium Fuel Fabrication	N/A	KNFC/Taejon	1989 - present	200 MTU (PWR)
		CANDU/Taejon	1994 - present	700 MTU (total) 350 MTU PWR & 400 MTU PHWR*
UO_2 Reconversion	N/A		1990 - present	200 MTU
Reprocessing	None			
MOX Fuel Fabrication	None			
LLW Disposal				
HLW Disposal	None			

* Italicized data from World Nuclear Industry Handbook 1998. Nuclear Engineering International. p. 120-127.

Exhibit 6-2. Non-Domestic Fuel Cycle Facilities Supplying South Korea

Fuel Cycle Step	Location	Company	Supplied to South Korea
Uranium Production	Australia	ERA	25% of national requirement
	Russia	Tenex	15% of national requirement
	Canada	Cameco	15% of national requirement
Conversion (U_3O_8 to UF_6)	France	COMURHEX	65% of commitments*
	Tenex	Tenex	25% of commitments*
	United Kingdom	BNFL	10% of commitments*
Enrichment	United States	USEC	50% of national requirements
	Russia	Tenex	25% of national requirements
	UK, Germany, and/or Netherlands	Urenco	Combined - 15% of national requirements

*Existing contractual commitments for conversion are less than national requirement.

7.0 The People's Republic of China

7.1 Nuclear Program

7.1.1 History to Date

The Chinese nuclear power industry began with a military program that later developed a civilian nuclear power program. The People's Republic of China (China) did not begin the peaceful use of nuclear energy until the 1980s, several decades after the start of military-related nuclear energy activities.

The Central People's Government Council (currently the State Council) established the Academy of Sciences of China and 22 research institutes in 1949, and this organization began to develop a nuclear power program following a nuclear power agreement with Soviet Union in 1955. In 1957, the Institute of Physics organized a research unit of atomic energy directly under the control of the Academy of Science. About this time, the People's Republic of China (PRC) negotiated a technological agreement on defense with the Soviet Union that provided for China to receive information and technology pertaining to nuclear technology for military purposes. In 1958, the same year that the PRC established its State Scientific and Technological Commission, the Soviet Union assisted the PRC in putting into operation a 7 to 10 MW heavy water experimental reactor.

After the Soviet Union unilaterally abrogated the nuclear assistance agreement in 1959 and withdrew its experts, the PRC continued to develop its nuclear capabilities. By 1963, it had five nuclear research reactors in operation. A gaseous diffusion enrichment plant in Lanzhou City, Gansu Province, also began operation in 1963. In 1964, the PRC conducted its first test of a nuclear bomb, and three years later announced successful testing of a hydrogen bomb. Thus, by the mid-1960's, the PRC had established the technological foundation for nuclear reactors and a nuclear fuel cycle. The Cultural Revolution, which started in 1968, distracted China from its nuclear program, and China did not embark on full-scale utilization of nuclear power for industrial purposes until much later. In 1980, the first meeting of the Chinese Nuclear Society initiated a move to actively promote nuclear power for peaceful purposes such as power generation and isotope and radiation applications.

The Chinese nuclear industry is organized around the China National Nuclear Corporation (CNNC), which is also responsible for China's nuclear weapons program. Established in 1988 under the authority of the State Council, the CNNC's primary responsibility is promoting and developing nuclear energy. It is also responsible for international cooperation in the field of nuclear energy and emergency management planning for nuclear facilities.

Reactors. In the early 1970s, China projected a future shortage of electricity and decided to add nuclear power as part of its energy supply structure. China started research and development on an indigenous plant design in the mid 1970s. In 1963, China began construction of a 300-MWe PWR unit at Qinshan, thus signaling the beginning of the Chinese nuclear industry. (No information on the startup date of this or other currently operating reactors in China.)

Fuel Cycle Facilities. Historical information on Chinese fuel cycle facilities is limited. However, China has developed complete front-end fuel cycle capabilities from uranium mining through fuel fabrication.

7.1.2 Current Status

The Chinese nuclear power industry is state-controlled and employs 5,000 nuclear professionals, the majority of them with Western academic credentials. The Daya Bay nuclear power plant, in particular, has educated technicians and engineers who study and train abroad. Moreover, technicians must receive state certifications from the Nuclear Security Bureau before they can be employed.

CNNC, the agency at the center of the Chinese nuclear program, has several daughter companies. The most visible of these outside of China is the China Nuclear Energy Industry Corporation (CNEIC), which acts as the export and import company for the CNNC. CNEIC actively sells fuel cycle services to utilities in Europe, the United States, and Japan. CNEIC also represents China's interests in foreign research and power reactor projects, including the Algerian HWR and the Pakistani power reactor, Chasma.

The China Institute of Atomic Energy (CIAE) conducts research and development for the nuclear energy industry, including FBR development. The Institute of Nuclear Technology (INET) carries out R&D as well, focusing on designing and building a low-temperature reactor.[60]

Reactors. China currently has three LWRs in operation. The Qinshan Station, located near Shanghai, has a 300-MWe domestically designed PWR in operation. The Daya Bay Station, located in Guangdong Province, has two 900-MWe PWRs in operation. The Daya Bay PWRs were supplied by Framatome, a French reactor vendor, and represent China's first large-scale nuclear power station, as well as the first to use foreign investment and Western equipment and technology.

In addition to the three currently operating PWRs at Qinshan and Daya Bay, China is also planning or constructing another 12 reactors. Eight of these are planned to be located at the Qinshan site, including four reactors currently under construction and four in the planning stage. The Qinshan units under construction include two domestically designed PWRs rated at 600 MWe that are larger versions of the original Qinshan PWR and two Canadian deuterium uranium (CANDU) PHWRs each rated at 700 MWe. The four Qinshan reactors in the planning stage include two 600-MWe PWRs and two PHWRs for a total of 9 reactors at that site.

[60] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/china/factsheet.html.

The four remaining reactors being planned or constructed include two French-designed 984-MWe units under construction at Lingao, about 2 kilometers from the existing plants at Daya Bay, and two 1,000-MWe class PWRs that China has agreed to purchase from Russia. The Russian VVER-1000 units are planned for construction in Lianyungang in Jiangsu Province, near Shanghai.

China's Qinshan nuclear power plant was domestically designed and produced, and the plant is managed without foreign affiliates. To date, its operations have run smoothly. China has already succeeded in marketing this technology by concluding an agreement with Pakistan for installation of a similar 300-MWe nuclear power plant at Chasma.

Uranium Supply. China's uranium deposits are located in the provinces of southern Anhui, Fujian, Guangdong, Guangxi, Hunan, southern Jiansu, Jiangxi, and Zhejiang. Additional reports suggest other deposits in Xinjiang, Qinghai, Inner Mongolia, and northeast China. The largest uranium mining sites are located in the province of Guangdong. Exact reserve figures are not publicly reported, although the IAEA indicates that about 64,000 MT uranium exist as known reserves. Current annual uranium production is about 600 tonnes uranium. This number is expected to increase when modernization of the uranium mill at Henyang is completed. Using reasonable projections of uranium availability and power plant demand, China can reasonably expect to be self-sufficent in uranium production for at least 20 years. To help satisfy its future uranium needs, China has begun to develop the following three uranium production sites, each of which is expected to produce about 100 MT uranium per year:

- Yining in-situ leach project
- Lantian heap leach project
- Benxi acid-ferric leach project

Conversion. CNNC operates a uranium conversion plant at its Lanzhou site. The plant capacity is estimated at 1,000 MTU per year.

Enrichment. China is self-sufficient with respect to uranium enrichment and is marketing enrichment services internationally. Chinese SWU capacity is currently about 1,000 MTSWU per year and is planned to reach about 1,400 MTSWU per year by 2002.

The original Chinese enrichment facilities are located at Lanzhou in Gansu province. The Lanzhou plant and a similar plant located near Chengdu have an estimated combined capacity of 400 MTSWU per year. Both plants use gaseous diffusion technology.

China recently commissioned a Russian-built gas centrifuge enrichment plant at Hauzhong, in Shaanxi province. The initial phase of the plant has a capacity of 200 MTSWU per year. There are two additional phases, one with a capacity of 200 MTSWU and another with 100 MTSWU, planned for this site.

Yet another enrichment plant, also based on Russian centrifuge technology, is to be located at the Lanzhou site. The capacity of this plant should be the same as the plant at Hauzhong (200 MTSWU).

Fuel Fabrication. China operates a PWR fuel fabrication facility in Yibin that is currently producing fuel for both Daya Bay PWRs and the Qinshan Unit 1 PWR. The annual design throughput is about 100 MTHM per year. China intends to expand the plant as required to maintain sufficient capacity to support all of the currently planned PWRs, including the Russian VVER-1000 units.

China plans to fabricate uranium fuel for the future Qinshan PHWRs at a plant in Baotu that is currently under construction. This facility will be capable of producing about 9,000 fuel assemblies per year to support the first two Qinshan PHWRs that are under construction. If the additional planned Qinshan PHWRs are constructed, the Baotu fabrication plant's capacity will need to be increased.

Reprocessing. China's fuel cycle plans call for spent fuel reprocessing and recycling the recovered plutonium. Reprocessing technology was developed as a part of China's nuclear weapons program. China has a pilot reprocessing plant at Lanzhou, and is planning a commercial scale plant at Yumen in Gansu province with a capacity of 800 MTHM per year. The Yumen site is very remote and requires long intermodal transport of spent fuel.

According to current Chinese plans, spent fuel will be cooled for 10 years before it is reprocessed. The fuel currently in the pools at Qinshan and Daya Bay has many years to go before it can be shipped for reprocessing.

ILW and LLW Disposal. CNNC plans to construct four regional disposal facilities, one in each quadrant of the country.

HLW Disposal. CIAE intends to build a pilot plant for the vitrification of HLW.[61]

7.1.3 Current Strategy

The government's ninth five-year plan guides the development of China's nuclear energy industry. It calls for constructing four large-scale nuclear power plants with eight reactors in Guangdong, Liaoning, and Zhejiang. This will increase nuclear power installed capacity from 1 percent of the national total in 1997, to 3 to 4 percent (approximately 20 GWe) of the national total by 2010, with subsequent increases thereafter. The Nuclear Power Institute of China (NPIC) is designing Qinshan II, a 600MWe PWR, and carrying out research on advanced PWRs. Shanghai Nuclear Engineering and Design Institute (SNERDI) is designing 300 MWe

[61] Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/china/factsheet.html.

PWRs intended for export.[62] Western reactor vendors view China as a significant future market. However, China intends to require vendors to enter agreements for technology transfer rather than purchasing plants on a turnkey basis.

China's nuclear policy is summarized in the following table:

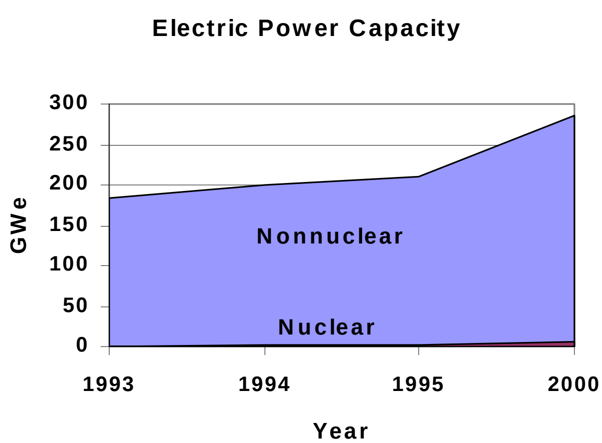
Area	Policy
Energy Policy	Expand electric generating capacity through development of the nuclear power program. Stabilize the energy infrastructure of the country and balance the uneven distribution of resources.
Nuclear	Introduce foreign reactor technology and enhance domestic technology to increase nuclear capacity.
Fuel Cycle	Utilize national uranium resources. Achieve domestic fuel enrichment and fabrication capacity. Develop spent fuel reprocessing technology.
Waste Management	Locate spent fuel storage in the reactor facilities as a short-term strategy. Develop reprocessing of fuel, HLW vitrification capacity, and a permanent repository.

[62] Ibid.

7.2 Statistics

7.2.1 Nuclear Profile

Total nuclear power production (1996)[63]	14 TWh
Percent of total power production that is nuclear (1996)[64]	1%
Total nuclear generating capacity (1997)[65]	2 GWe
Percent of total power capacity that is nuclear (1997)[66]	1%
Number of operating commercial reactors[67] TOTAL PWR	 3 3
Percent of world nuclear generating capacity	1%



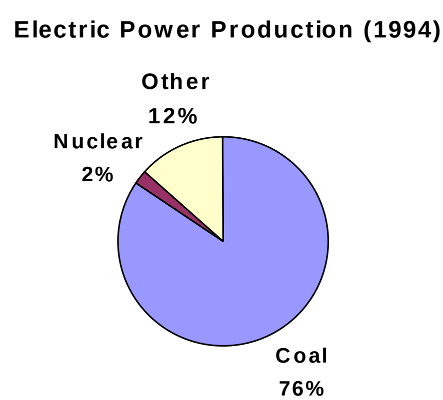


Chart data from: Pacific Northwest National Laboratory. http://etd.pnl.gov:2080/fac/china/factsheet.html.

[63] 1996 data from IAEA.

[64] Ibid.

[65] *World Nuclear Performance*. February 1998. Volume 13, Issue 2.

[66] Ibid.

[67] *World Nuclear Industry Handbook 1998*. Nuclear Engineering International.

7.2.2 Fuel Cycle Facilities

Exhibit 7-1. Commercial Nuclear Fuel Cycle Facilities Located in China

Fuel Cycle Step	National Requirement (1998)	Company/Facility	Operating Period	Capacity Data (annual)
Uranium Production	500 MT U_3O_8	*CNNC/Hengyang, Hengian, Qinlong, Yining*	- present	Reserves - 64,000 MTU Production - 600 MTU (currently) *Capacity - Over 1,100 MTU at Hengyang alone*
		/Yining In-situ leach	Not yet operating	100 MTU
		/Lantian heap leach	Not yet operating	100 MTU
		/Benxi acid-ferric leach	Not yet operating	100 MTU
Conversion (U_3O_8 to UF_6)	440 MTU	CNNC/Lanzhou	- Present	1000 MTU
Enrichment	240 MTSWU	/Lanzhou	1963 - Present	*200 MTSWU* (gaseous diffusion)
		/Changdu	- Present	*200 MTSWU* (gaseous diffusion)
		/Hauzhong	Recent - Present	200 MTSWU (current) 500 MTSWU (total planned) (gas centrifuge)
		/Lanzhou	*1996 - present*	*200 MTSWU* *(gas diffusion)*
Uranium Fuel Fabrication	60 MTHM	CNNC/*Yibin*	*1987 - present*	*150 MTHM LWR*
		/Baotu	Under construction	9,000 PHWR assemblies

Exhibit 7-2. Non-Domestic Nuclear Fuel Cycle Facilities Supplying China

Fuel Cycle Step	Location	Company	Operating Period	Supplied to China
China is self-sufficient in meeting its nuclear fuel cycle supply needs.				

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Appendix A. Nuclear Profile Comparison

Exhibit A-1
Commercial Nuclear Power Production and Capacity[68]

Nation	Nuclear Production		Nuclear Capacity	
	TWh	Percent Nuclear	GWe	Percent of World Nuclear Capacity
France	370	78%	58	24%
Japan	290	35%	43	19%
Germany	160	30%	22	9%
Russia	110	13%	20	8%
United Kingdom	90	26%	14	6%
South Korea	70	35%	10	4%
China	12	1%	2	1%

Exhibit A-2
Prospective Future Nuclear Plants[69]

Nation	Under Construction					Planned	Proposed
	PWR	VVER	BWR	PHWR	RBMK		
China	4 / 3,200	0	0	2 / 1,400	0	2 / 2,000	(Many)
South Korea	3 / 3,050	0	0	2 / 1,400	0	10 / 11,200	0
Russia	0	3 / 2,630	0	0	1 / 1,000	5 / 2,930	23 / 11,906
Japan	0	0	2 / 1,925	0	0	7 / 8,675	16 / 20,075
France	1 / 1,516	0	0	0	0	0	2 / 2,900
Germany	None						
UK	None						

* Number of plants/nuclear capacity of plants in MWe

[68] Sources: International Atomic Energy Agency; *Nuclear Briefing Paper*, NAC unpublished report. 1998.

[69] Source: Nuclear Engineering International. *World Nuclear Industry Handbook 1998.*

Exhibit A-3 Operating Commercial Nuclear Power Plants

Nation	Total	PWR	VVER	BWR	AGR	Magnox	RBMK	FBR	Other
France	58 / 64,330	57 / 64,080	0	0	0	0	0	1 / 250	0
Japan	54 / 45,528	23 / 19,366	0	28 / 25,551	0	1 / 166	0	1 / 280	1 / 165
UK	35 / 14,208	1 / 1,258	0	0	14 / 9,164	20 / 3,786	0	0	0
Russia	29 / 21,242	0	13 / 9,594	0	0	0	11 / 11,000	1 / 600	4 / 48
Germany	19 / 22,033	13 / 15,404	0	6 / 6,629	0	0	0	0	0
South Korea	13 / 11,389	11 / 9,995	0	0	0	0	2 / 2,600	0	0
China	3 / 2,268	3 / 2,268	0	0	0	0	0	0	0

* Number of plants/nuclear capacity of plants in Mwe
Source: Nuclear Engineering International. *World Nuclear Industry Handbook*.

Appendix B. List of Acronyms

ABWR	advanced boiling water reactor
AEB	Atomic Energy Bureau
AEC	Atomic Energy Commission
ANDRA	France's national agency for radioactive waste management
ATR	advanced thermal reactor
BE	British Energy
BGR	Bundesanstalt fur Geowissenschaften und Rohstoffe
BMBF	BundesMinisterium fur Bildung, Wissenschaft, Forschung, und Technologie
BMF	Federal Ministry of Finance (German)
BMU	Bundesministerium fur Umwelt
BMWi	Federal Ministry for Economics (German)
BN	fast reactor
BNFL	British Nuclear Fuels
BWR	boiling water reactor
CANDU	Canadian deuterium uranium
CEGB	Central Electricity Generating Board
CEA	Commissariat a l'Energie Atomique
CFCa	Complex de Fabrication de Cadarache
CNEIC	China Nuclear Energy Industry Corporation
CNNC	China National Nuclear Corporation
COGEMA	Compagnie Generale des Matieres Nucleaires
COMHUREX	Societe pour la Conversion de Uranium en Metal et en Hexafluorure
CRIEPI	Central Research Institute of Electric Power Industry
EDF	Electricite de France
EPDC	Electric Power Development Corporation
ERA	Energy Resources of Australia
EUCF	Enriched Uranium Chemical Facility
FBFC	Franco-Belge de Fabrication des Combustibles
FBR	fast breeder reactor
FSU	former Soviet Union
FZK	Forschungs Zentrum Karlsruhe
GCR	Gas-Cooled Reactor
GDR	former East Germany
GE	General Electric
GNS	company for nuclear service
GWe	gigawatts electric
GWh	gigawatt hours
HEU	highly enriched uranium (U235)
HLW	high level waste
HWR	heavy-water reactor
JAERI	Japan Atomic Energy Research Institute
JAPC	Japan Atomic Power Company

JDPR	Japan Demonstration Power Reactor
JNFL	Japan Nuclear Fuels Ltd.
KAERI	Korea Atomic Energy Research Institute
KEPCO	Korea Electric Power Company
KMRR	Korea Multipurpose Research Reactor
KNFC	Korea Nuclear Fuel Company Ltd.
KSNPP	Korean Standard Nuclear Power Plants
IAEA	International Atomic Energy Agency
ILW	intermediate-level waste
IPCR	Institute of Physical and Chemical Research
LLW	low-level waste
LWR	light-water reactor
MEI	Ministry of Economics and Industry
MEST	Ministry of Education, Science, and Technology
MITI	Ministry of International Trade and Industry
MT	metric tons
MTHM	metric tons heavy metal
MTSWU	metric tons separative work unit
MTU	metric tons uranium
NETEC	Nuclear Environment Technical institute
NE	Nuclear Electric
NIRS	National Institute of Radiological Science
NPT	Nuclear Non-Proliferation Treaty
NUGG	Natural-Uranium Gas-Graphite
NSB	National Safety Bureau
NSC	Nuclear Safety Commission
PHWR	pressurized heavy water reactor
PNC	Power Reactor and Nuclear Fuel Development Corporation
PRC	People's Republic of China
RBMK	graphite-moderated, channel type boiling water reactor
RC	Radiation Council
RepU	reprocessed uranium
R&D	research and development
SNF	spent nuclear fuel
SNL	Scottish Nuclear
SSEB	South of Scotland Electricity
STA	Science and Technology Agency
THORPE	Thermal Oxide Reprocessing Plant
TOR	Traitement Oxyde Rapide
TRIGA	Training Research and Isotope production General Atomics
TRP	Tokyo Reprocessing Plant
TRU	transuranic waste
TWe	terawatts electric
TWh	terawatt hour
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority

UP1,2,3	Usine de Plutonium 1,2,3
VKTA	Verein fur Kernverfahrenstechnik und Analytik
WAK	Wiederaufarbeitungsanlage
WNP	world nuclear performance

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